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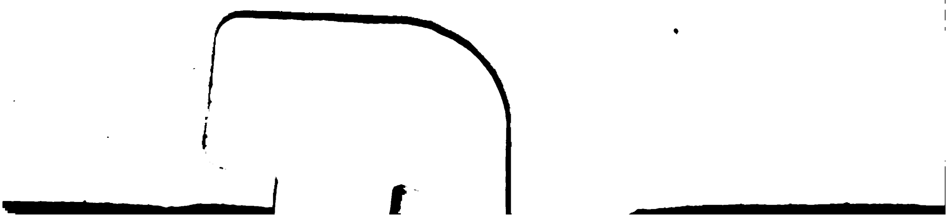

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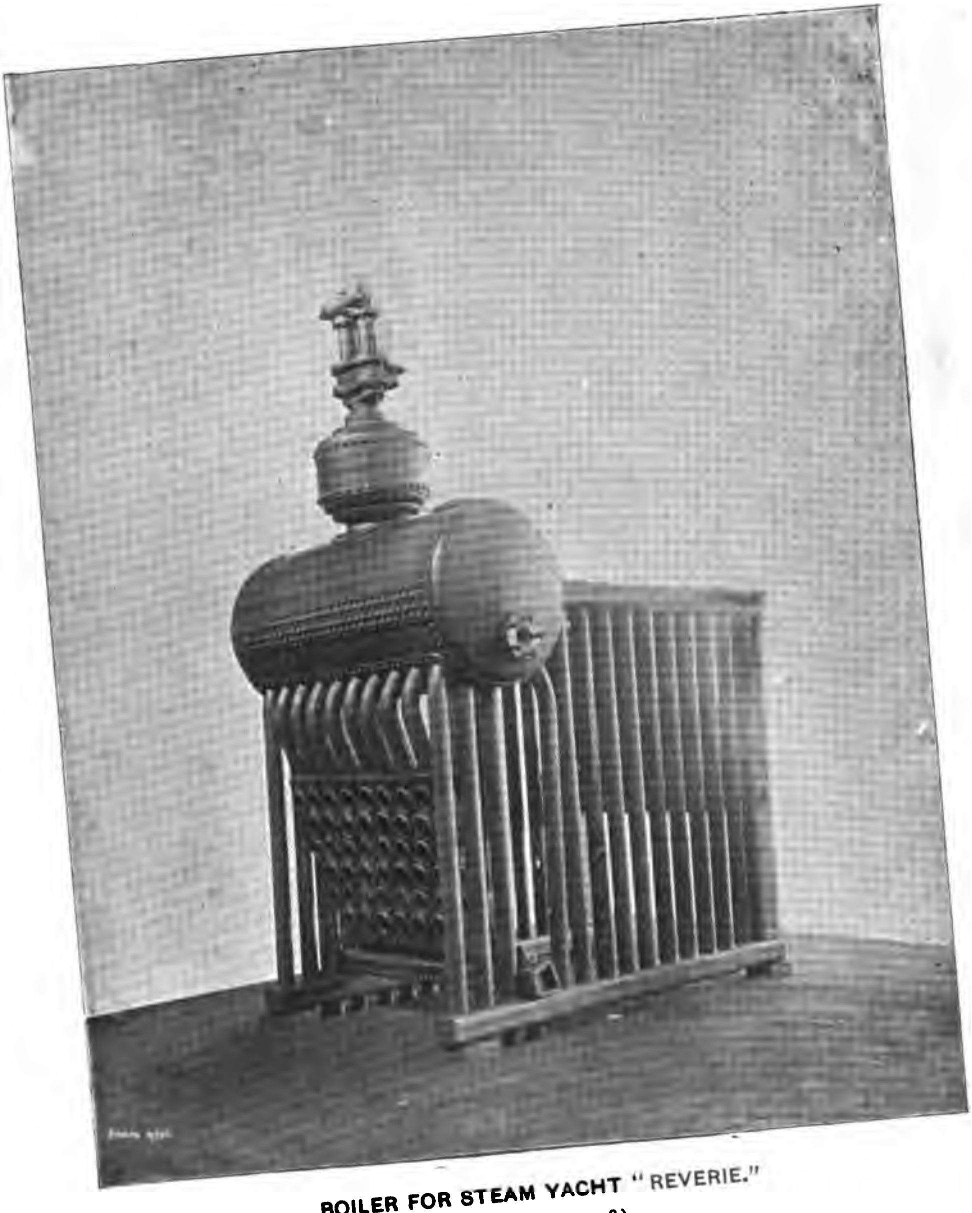

BOILER FOR STEAM YACHT "REVERIE."

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MECHANICAL REFRIGERATION AND ICE MAKING.

BY PAUL MELLEN CHAMBERLAIN, M.E., '90.

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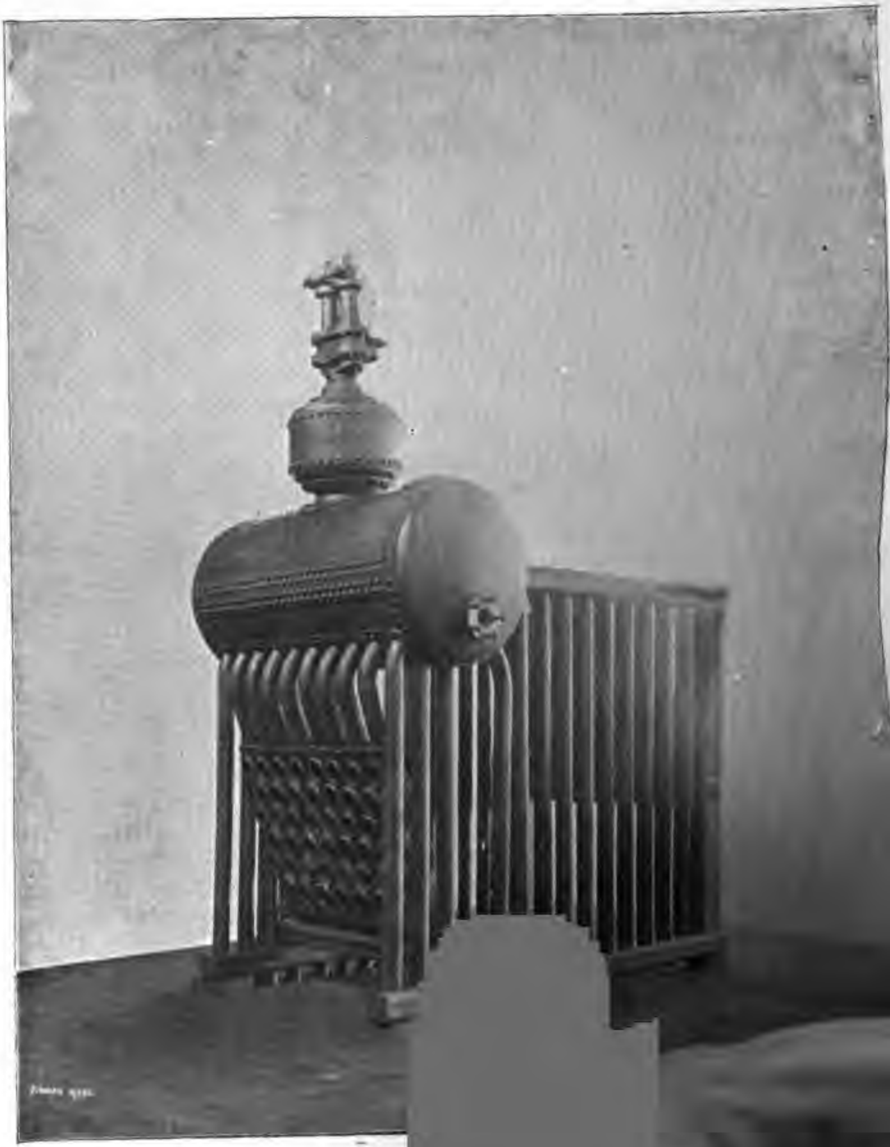

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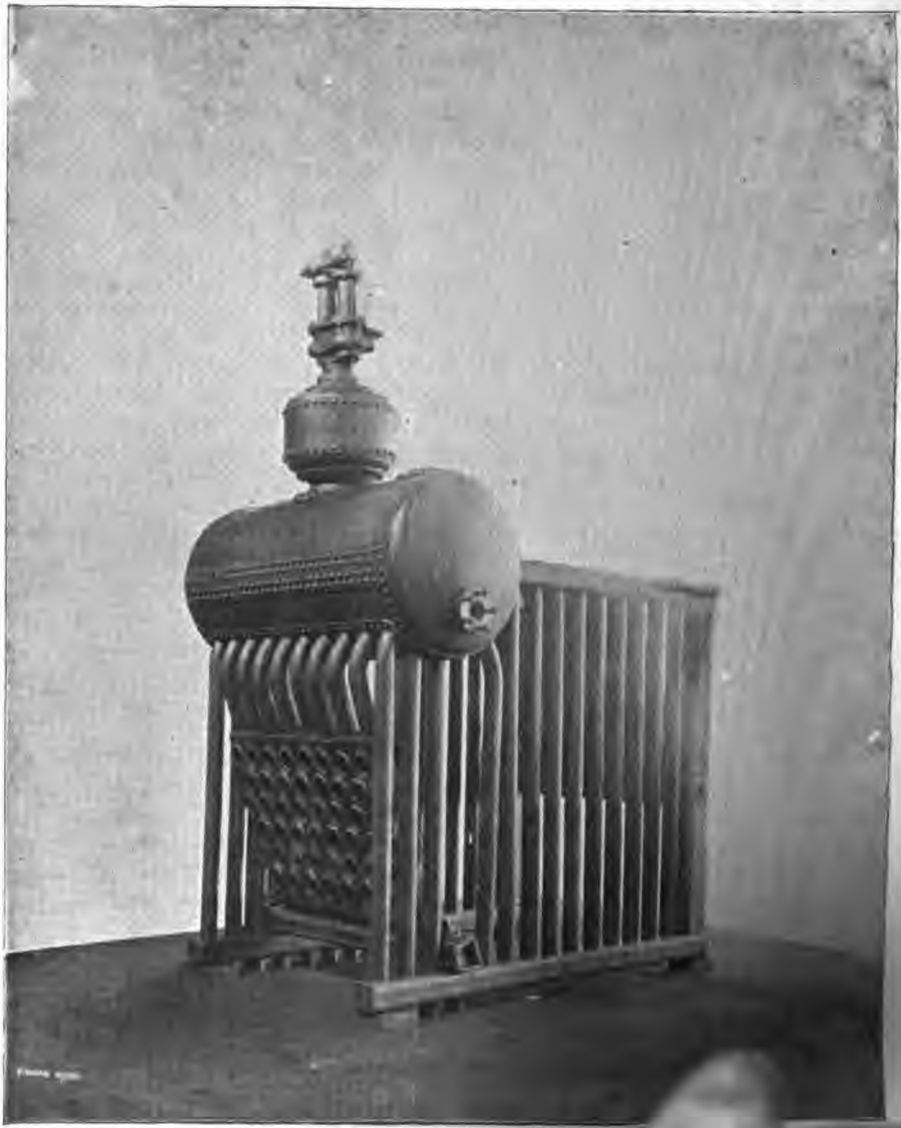

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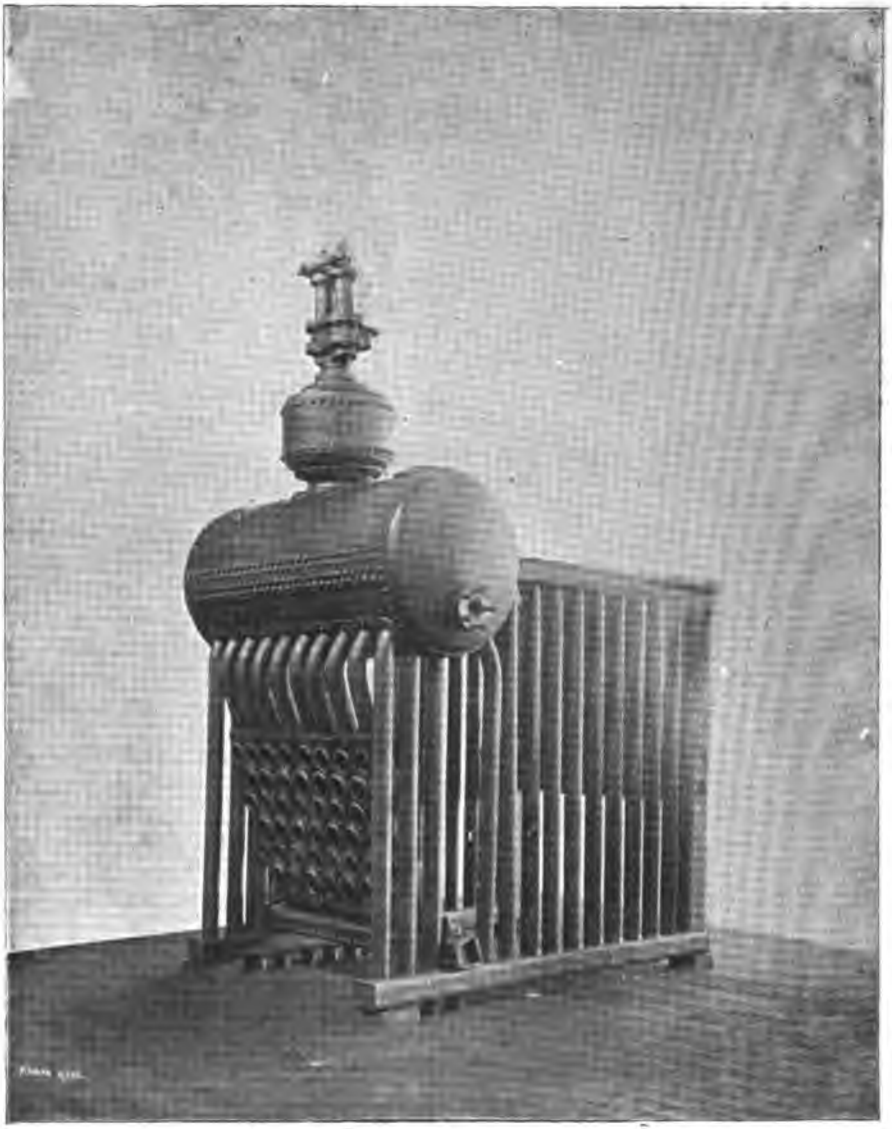

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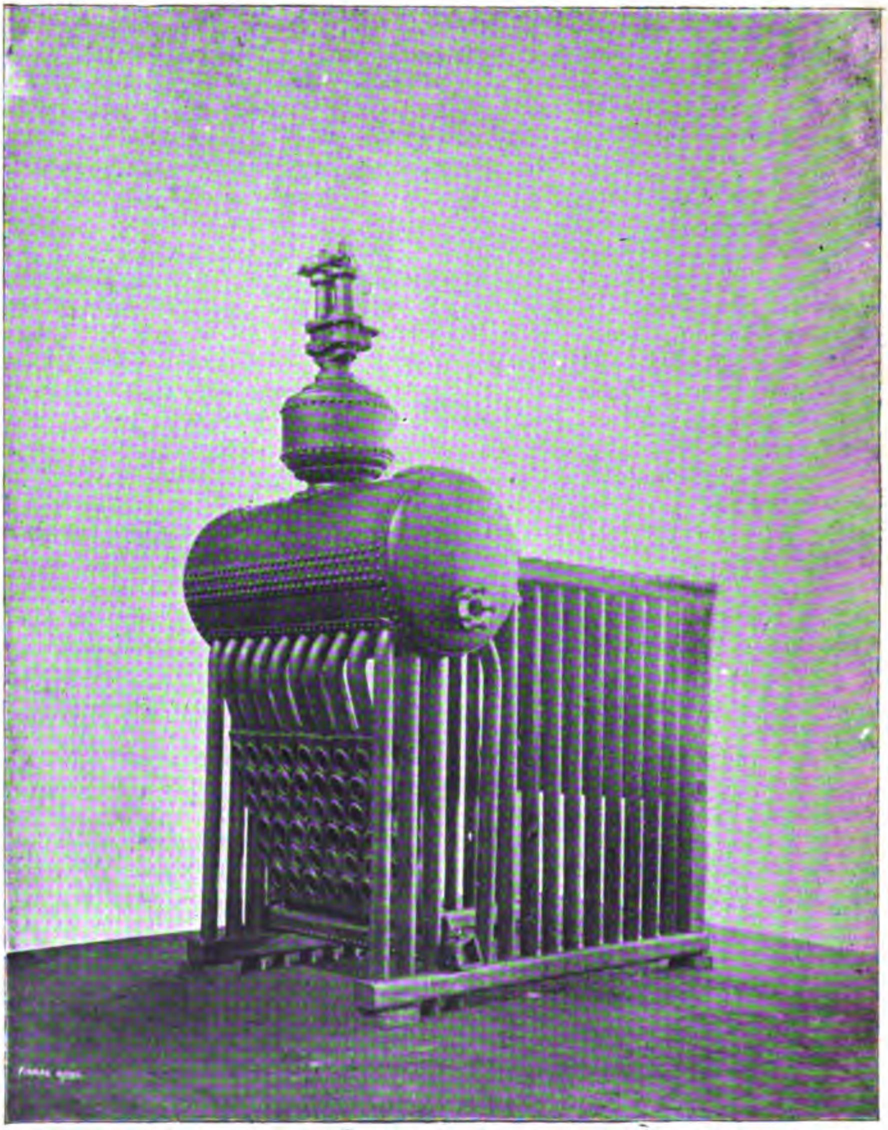

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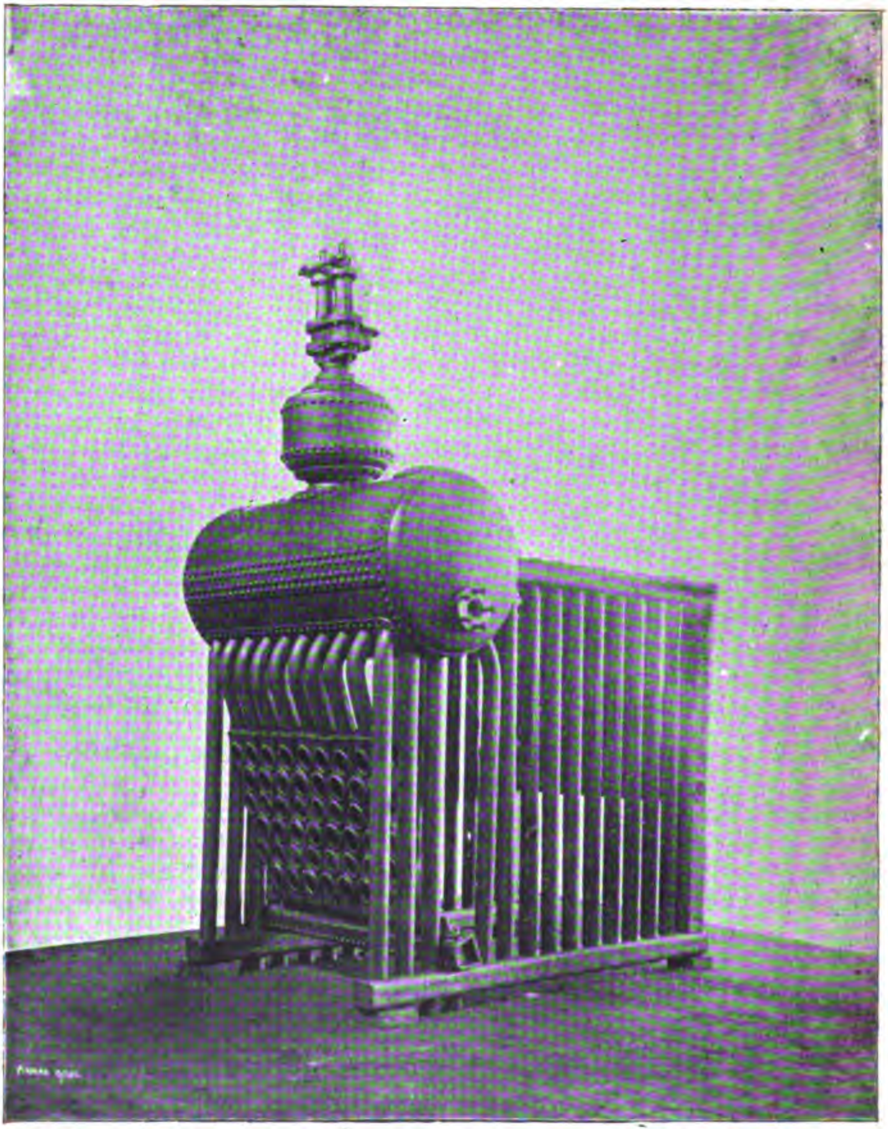

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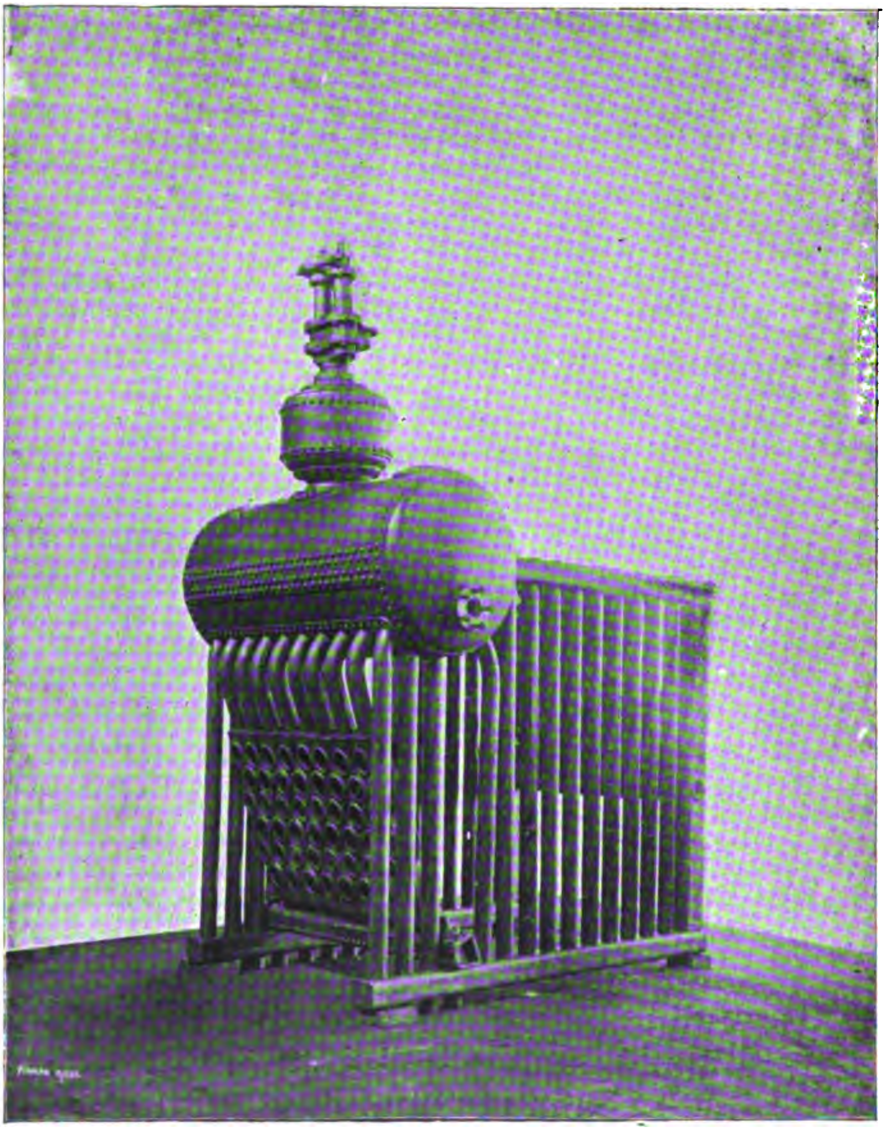

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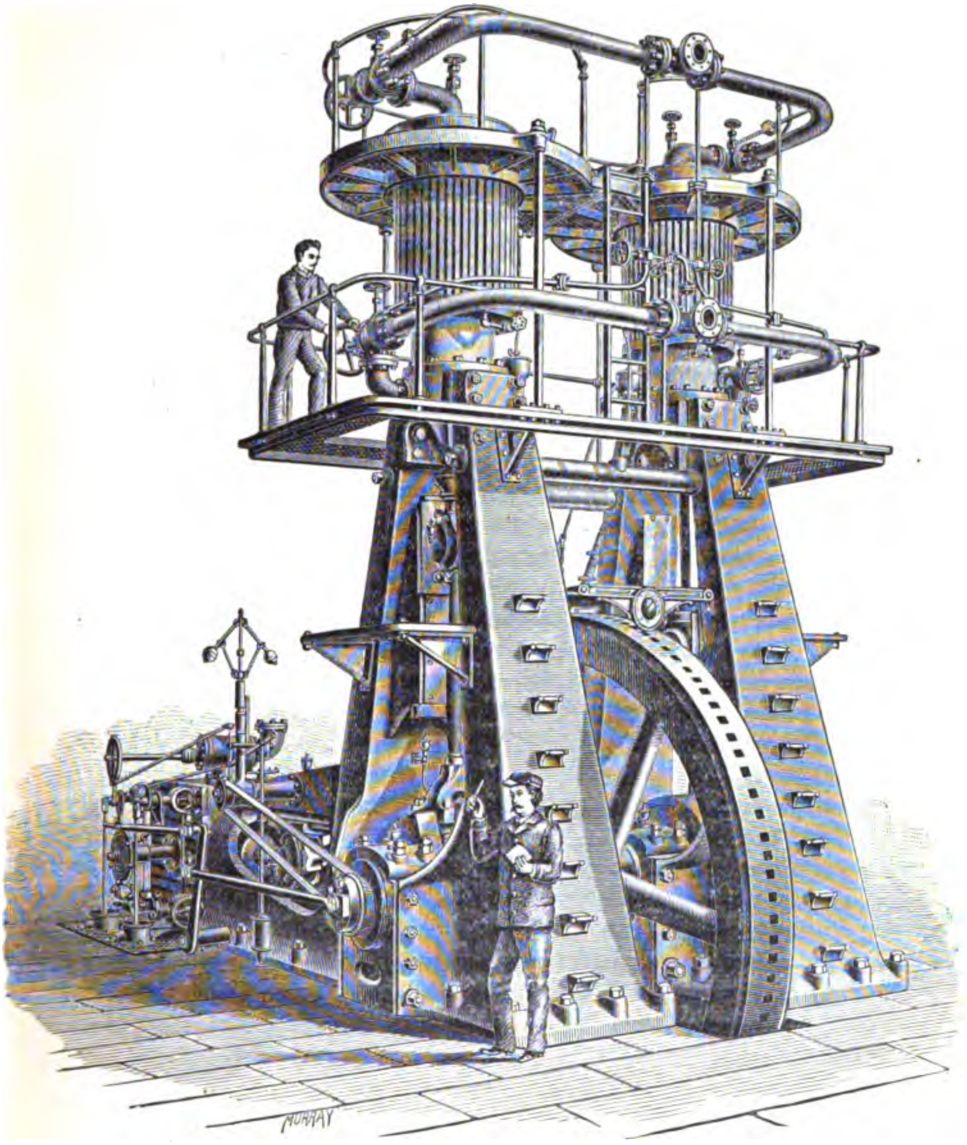
never produced. We bring a cold object (one which has little molecular motion) near a warm one, and the heat from the latter is communicated to the cooler until the temperatures are equal, the cooler one having gained heat, and the warmer one having lost a corresponding amount. We put a piece of ice in a vessel of water, the water gives up its heat to the ice which melts and, as we commonly say, "cools the water"; what actually takes place is a reduction of the molecular energy of the water, this energy having been employed to increase that of the ice.

By compressing an elastic substance we increase its molecular energy, and hence increase its temperature; this may be best illustrated with gas, but often is exhibited in solids. Take, for instance, the compression of a piece of iron as exhibited in the punching of a rivet hole or the hammering on a nail. If we take a gas enclosed in a cylinder and compress it by means of pressure on a piston, the mechanical energy employed will be transformed into heat, the temperature will immediately rise, that is, the molecular energy will be increased. If the pressure be removed and no heat be allowed to escape, the temperature will return to its original degree. If, however, while in a state of compression the heat is allowed to escape, the gas will not return to its original volume until an amount of heat equal to the loss is supplied; that is, by compressing a gas and causing it to liquify by abstracting the heat, when the liquid is allowed to evaporate (expand), heat will be communicated to it from surrounding objects equal to the amount abstracted during compression. For example, let us take a cylinder full of gas and compress it, allowing a stream of cool water (well or hydrant) to flow over the exterior of the cylinder, the heat caused by compression will be carried away by the water as it is cooler than the gas. Now immerse this cylinder with its cooled compressed gas in a vessel containing oil or mercury and allow the gas to expand in the cylinder, the pressure having been taken from the piston, the result will be the taking up from the surrounding fluid, heat equal to that lost by the gas to the flowing water. Repeat this operation a sufficient number of times thus taking heat from the oil or mercury until its temperature is below freezing point. Then if we take a can of water and lower it into the cold fluid, the heat of the water will be taken up by the outer fluid until the temperature of the water is reduced to the freezing point, and ultimately frozen. We would thus have manufactured ice. Had we placed this cooling fluid in an insulated box we would have direct mechanical refrigeration.



There have been many different gases used for the working medium of refrigerating machines, but at the present time the larger number of compression machine builders have adopted anhydrous ammonia ($N\,H_4$) as possessing the largest number of desirable qualities. To facilitate the description of some of the details of a working machine, reference will be made to the accompanying cut, which was provided by the courtesy of Frick Company, Engineers, who stand in the front rank of successful machine designers and builders. As shown in the cut the power is supplied by a steam cylinder which connects direct to a crank shaft which carries the balance wheel, and also drives the compression cylinders shown on top of the columns. The gas is drawn in at the lower end of the compressors where it is compressed by the upward stroke of the compressor piston, and forced at a high pressure through pipes to a higher level where it flows through coils, over which cold water is flowing, which carries away the heat of compression. The compression cylinders are jacketed for cold water which flowing through assists the liquifying process. The liquified ammonia after having passed through the cooling coils, or condenser as it is called, is stored in a wrought iron tank, from which it is allowed to expand or evaporate into coils of pipe which are passed to and fro in a tank containing brine, whose function is the same as that of the mercury or oil used for illustration in the previous pages. Brine is used instead of a more costly fluid, because it can be reduced to a very low temperature without freezing. This brine is simply a medium for the transfer of heat and its use is in no way analogous to that of the brine in an ice cream freezer, where it performs a chemical function.

The system thus far is the same either for refrigerating or ice-making. If it be for the former the chilled brine is passed by pipes through the rooms where refrigeration is required, where it gathers up heat, and is returned to the tank where it again gives up its heat to the liquified gas expanding in the ammonia coils. This expanded gas is conveyed to the ammonia compressors where it is again compressed, cooled and liquified, and repeats the cycle over and over. In the case of "can" ice-making, the brine tank is arranged to allow cans of water to be lowered into the brine, which carrying away the heat of the water allows it to freeze. Owing to the good absorbent qualities of water it is found necessary to purify it for manufactured ice, which is done by filtration and distillation. The steam as it is exhausted from the steam cylinder of the engine is carried through a trap which catches the oil that has gone through the cylinder with it, thence to a tank filled with coke which abstracts other extraneous substances, and thence to a condenser. The condenser is an arrangement of radial coils submerged in water, the water, which has already been used on the ammonia condenser, passing through, being still cool enough to condense the steam. The condensed steam is passed to a tank where it is boiled to expel what air it may have taken up in its travels, thence successively through a filter filled with charcoal, through coils over which cold water is flowing to cool it, through another filter of bone-black, still through more filters filled with sponge, and thence to the cold storage tank where it is used as needed to fill the ice moulds. It is found that the ammonia gas after having done its work in the brine tank still has some expansive tendency, so it is passed through coils in the cold water storage tank, thereby further cooling the distilled water before running it into the cans or moulds where it is to be frozen.

The above process is known as the can or mould system, and is used most generally. There is another system known as the plate system, but owing to lack of space it may not be well to describe it further than to say that large plates are frozen to the side of cells which are immersed in water, the brine being in the cells and cooled by evaporating coils running through the same. The ice frozen in this manner more resembles nature's product in transparency, and furthermore requires no distilled water, all impurities being thrown outward in process of freezing.

APPLICATION OF HIRN'S ANALYSIS TO ENGINE-TESTING.*

BY PROF. R. C. CARPENTER.

The methods proposed by Hirn, to be used in the testing of engines, are familiar to the members of the society from papers which have already been presented by M. V. Dwelshauvers-Dery and others.†

I have made the attempt to reduce the analysis to a form readily applicable to ordinary testing, and a large class of students have made an application to a simple condensing engine with plain slide valve, and throttling governor. In addition, other tests with applications of this analysis have been made to an automatic engine and to a triple expansion engine.

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* Abstract of paper presented at the Providence meeting of the American Society of Mechanical Engineers (1891).

† *Transactions*, Vol. XI, No. CCXIX, and Vol. XI, No. CCCLXXXII, papers by Messrs. Dwelshauvers-Dery and R. H. Thurston. See also the manuals by the last-named on Engines, Boilers, and Engine and Boiler Trials; New York: J. Wiley & Sons.

During the tests on the plain slide valve engine, an attempt was made, with a fair degree of success, to measure the quality of the steam remaining in the clearance space during compression, and a description of this method constitutes the latter and more important part of this paper.

It is proposed in the paper to present the methods used and the results obtained in those tests and also discussions relating to the quality of steam by various authors.

In order to call to mind the character of analysis proposed by Hirn, which I have reason to think has not been applied to engine-testing to any great extent in this country, and to show what Hirn proposed and what has been accomplished, I present the translation—in which I have endeavored to preserve the structure of the original—of a few pages from the French edition of the "*Traité des Machines à Vapeur*, par Francesco Singaglia, traduit l'Italien, par E. De Billy" (Paris, 1890). "As, probably, now well known, this method requires more data than the usual methods of testing, and requires more labor in reduction, but considering the information regarding the distribution of heat and power which is furnished, it will, I think, repay the closest examination, and the adoption in all tests where it may be found practicable."

HIRN'S THEORY.

Practical and General Theory of the Engine.—The practical or experimental theory of the steam-engine, or, if you please, the calorimetric method applied to that study, rests upon an examination itself of the motive power, and not upon hypotheses agreeing badly with the facts. One easily understands that an analysis of an actual engine can only be made experimentally, because it is necessary in this study to take account of the modifications arising from the permeability of the metal to heat and of various complex phenomena; to such an extent is this true that in the general theory of an heat engine, it is absolutely indispensable to proceed to a special study of each phenomenon independently of the others. We shall see what important practical questions experimental analysis has investigated, and the number of erroneous opinions that it has destroyed. It is that which will resolve, by patient study of facts, all the discussions and controversies really pending.

Notice with what simplicity Professor Dwelshauvers-Dery expresses the theory of Hirn :

Between any two positions of the piston, the quantity of heat which has done external work, and that which is exchanged between the metal and the steam, form a sum equal to the difference between the amount of heat in the steam in those positions ; increased, if necessary, *by the heat that may have been introduced with new steam, or diminished by that which may have left the cylinder.*

The *general* thermo-dynamical theory, which takes as true a law of constant expansion in all cases, and neglects the exchange of heat between the metal and steam, furnishes approximate results for the work and expenditure of steam, which often deviate much from the truth. This method can, nevertheless, furnish valuable indications, and lead to the discovery of real facts.

But experiment only sanctions, corrects and determines the advantage or inconvenience of any modification whatever, and constitutes a check or corrective for the general theory. In fact, changes which at first sight seem insignificant, perceptibly modify the economy in the development of an engine or machine. Thus the increase of intelligence regarding the exhaust, and the condition of the steam from the admission to the release, have produced in the engine an economy increasing as 9 to 100 in the consumption of steam.

It is well known that, in addition to Mariotte's law for the expansion of steam, there is that of adiabatic expansion, which consists in supposing that the vapor being homogeneous between the metal and liquid in contact, there is no exchange of heat in spite of the difference in temperature. Very probably the steam at the end of admission will not be homogeneous ; nevertheless we can allow that it may be so, not knowing what hypothesis to have recourse to, without falling absolutely into arbitrary methods ; but it is impossible to admit that there is no exchange of heat.

METHOD OF TESTING USED BY HIRN.

Experiments at the School in Alsace.—In order to experiment with an engine, it is necessary to make it work for one or more days under a determinate system of pressure and expansion, performing constant work. The quantity of feed-water used by the boiler is measured for one day, for example, while taking care that the level does not vary, or at least that it is the same at the beginning and end of the experiment ; then dividing this quantity by the number of strokes of the piston, the amount of water used at each stroke will be obtained. It is also necessary to measure the quantity of water mechanically entrained by the steam entering the cylinder, the quantity of water of condensation, its temperature on entering the condenser, and also its temperature on leaving the condenser, the pressure of the steam, and the amount of work indicated.

When it is possible, and when the force of the engine does not exceed a certain limit, 100 H. P., for instance (for beyond that limit the operation would be dangerous), measure at frequent intervals, from hour to hour, and even oftener—the effective work with a Prony brake, taking care that at each measure the engine returns to its former condition. If one cannot make use of the brake, it is necessary to measure the work of the unloaded engine by means of the Indicator. From this it is easy to calculate the work from friction when the engine works with a useful load.

In a series of well-known experiments, Hirn has demonstrated the thermometric action of the metallic walls of the cylinder, and he has determined numerically the error which is made when one estimates the work and expenditure of steam on the hypothesis of impermeability of the walls to heat.

All the ideas that we have regarding heat engines proceed from the science of thermodynamics; as Hirn would say were he able, "without this science any experimental theory is impossible." But we ought to notice that if this science is indispensable in guiding us in the analysis of a machine not already constructed, it cannot be of use to us in the previous study of that machine since we ignore the thermic conditions of the working of the steam.

The quantity of water entrained mechanically, which varies from boiler to boiler, and even in the same boiler varies from one instant to another, the fall of pressure between the boiler and cylinder, which depends likewise on the dimensions of the admission ports, the exchange of heat between the metal and steam, etc., are quantities not to be determined by pure theory. The indicated work is a quantity essentially experimental and can be determined only by the steam-engine indicator. But the indicator diagram once obtained, we are able, by the application of physics and thermodynamics to determine the weight of the steam, the temperature, pressure, the heat given up to the walls or that which has been returned from the walls.

But this only suffices to establish that the practical results are quite different from those which the general theory furnishes, it was still necessary to measure the amount of error made in order to deduce its industrial importance. That is what Hirn has done, aided by two experimenters of uncommon ability, Le Loutre and the regretted Hallauer, who was the most correct expounder of his master's thoughts. Thanks to them it is now established that the walls whose action varies with the construction of the engine, with the state of the steam, saturated or superheated, by the use of the steam-jacket or the condenser, have a chief influence over the yield of work and the thermic transformations.

ZEUNER'S OBJECTIONS.

The experiments of the Alsacian school were recently the object of profound criticism on the part of Zeuner, who found fault especially with the relative results in the action of the cylinder walls. The objections of Zeuner were refuted by Hirn and Hallauer.

Zeuner's first objection has reference to an hypothesis of Hirn, who had supposed by inference in his experiments the pressure of the boiler equal to that of the cylinder during admission, thus neglecting the throttling of the fluid vein at the entrance to the cylinder. Hirn recognized the justice of this criticism, but he demonstrated by examples that his calculations contain an approximation more than sufficient for the estimate of heat given up to the walls, if one neglects the weight of steam in the clearance space. Neither does Zeuner admit as correct the method of calculation often used by the Alsacians, which consists in neglecting absolutely to consider the weight of vapor enclosed in the clearance space. It should be observed here that in condensing engines, working without compression, this weight is small because of the feeble pressure of steam, and that afterward it might be computed by supposing that its density remains constant. But it is certainly not the same if there is compression, for this produces phenomena which are far from being negligible.

But the principal point of Zeuner's criticism is, that he offers equal objection to Hirn's second hypothesis. When he wishes to take account of the steam that remains behind the piston at the beginning of compression; that is to say, at the end of the exhaust, Hirn *considers it as saturated and dry.* According to Zeuner the thermic phenomena which the Alsacians attribute to the action of the walls exclusively, would be due in part only to those walls, and would be due in a larger proportion to a certain quantity of water which would always be found in the cylinder, so that the vapor would never be saturated and dry, and that Hirn's hypothesis would be inadmissible. But Hirn denies absolutely that water can exist permanently behind the piston when superheated steam is made use of, or when the cylinder is enclosed by a steam-jacket; he admits that it can exist in a steam-engine using saturated steam and without a steam-jacket; but he shows that this quantity is always very little and that it still comes from the action of the walls. Hallauer has proved in his turn by means of new calculations the hypothesis in question. He has taken up the analysis of the experiments of 1873 and 1875, supposing that, 1st, the compression is too small to be taken into account, and that the weight of the vapor and water behind the piston is nothing; 2d, that the steam which is compressed in the cylinder is not a quantity to be ignored, but that it is saturated and dry; 3d, the vapor which is compressed is not to be neglected, but contains a determinate weight of water.

From his calculations he finds that the differences between the results, which the three hypotheses produce, are within the limits of experimental errors.

In regard to the effect of the steam in the clearance space, Zeuner in *La Theorie Mécanique de la Chaleur*, makes the following statements:

"Clearance exerts an important influence upon the working. Its inconveniences are mainly due to the fact that steam is admitted into a space holding steam of feeble tension, so that the engine uses more than one without such dead spaces. It is true that the work which corresponds to this additional mass of steam is not entirely lost, since it shares in the expansion. In spite of this the work is too great to be neglected." Further, he states that if the compression be carried until boiler pressure is reached, "the engine then acts as one without clearance," but in that case the work of compressing the steam may equal the gain by the process.

"While the piston retrogrades a certain space, a corresponding volume of steam leaves the cylinder; the steam remaining behind probably containing a little water. Now as the mixture is compressed, there will probably result a partial or total vaporization of the water; and it may happen that at the limit of compression the steam in the dead space will be superheated. Unfortunately, we do not yet know how the mixture of this superheated vapor and the saturated steam from the boiler is effected; but this question is of little importance, the main object being to show that compression is accompanied by a vaporization of the water, mixed with steam, so as to cause superheating in the steam left behind."

APPLICATION OF HIRN'S ANALYSIS.

The following pages present, in as brief a form as possible, the method of application of Hirn's analysis, as adopted for a regular laboratory exercise for the advanced students in Sibley College.

The detailed method of making the analysis is easily understood, and is as follows: First, make a run as explained with constant load, taking determinations of quality, of entering steam, pressure and weight. The latter may be obtained either by condensing the steam or measuring the feed-water.

Also, measure the condensing water and the gain in temperature.

The log (see form No. 1)* is provided with columns for these measurements and such others as may be necessary, or can be taken as a check on the work. The log is especially adapted to the throttling calorimeter, with which most of the determinations of the quality of steam were made. In case the steam was too wet for the throttling calorimeter, the separator calorimeter was used. A calorimeter, to be described later, was attached to the steam-cylinder, and was provided with an automatic valve, so that steam could be admitted to the calorimeter during any desired portion of the stroke by the action of the engine. The quality of the steam in the exhaust may in some instances be determined, in which case valuable checks would be had on the accuracy of all the previous calculations; but in the trials in question, such determinations were not made, although space is provided in all the forms used. All apparatus used was calibrated and results recorded on the blank form No. 2.

Indicator cards were taken at frequent intervals during the run. On these cards were laid off initial lines for volume in accordance with the measures of clearance, and initial lines of pressure in accordance with the barometer reading. The cards were then subdivided by ordinates drawn to the points of cut-off, release, beginning of compression and of admission, thus dividing the diagram into four parts, corresponding to the periods of admission, expansion, exhaust and compression.

In the figures (Figs. 1 and 2) these ordinates are drawn from the points *b*, *c*, *d*, and *e* respectively. The measuer of these ordinates to the proper scale gives the absolute pressures and are filled in the proper columns in the special blank form 3. The areas, into which the card is divided, are then measured by the external

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* The special forms can be had by application to any of the Instructing force of the Mechanical Laboratory.

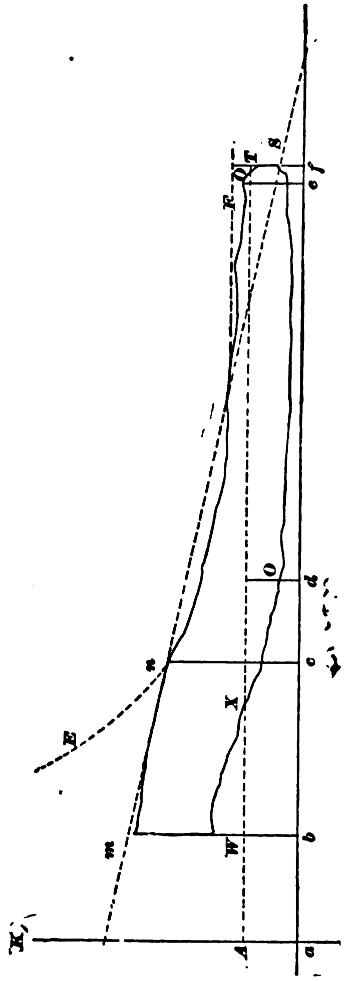


Fig. 1.

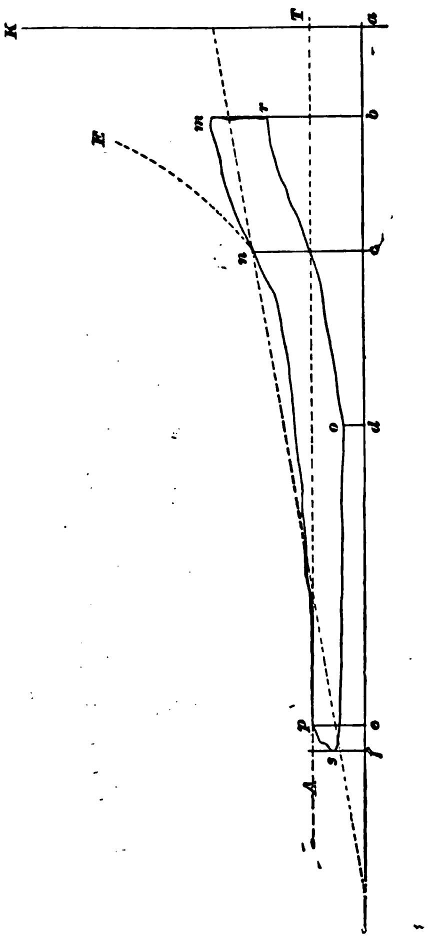


Fig. 2.

work, thus in Fig. 2 the area *brmncb* is proportional to the external work of admission ; *cnpec* to that of expansion ; *epste* minus *sfdos* to that of exhaust ; *dorbd* to that of compression. It is to be noticed that the work of exhaust and compression is essentially negative, and that the algebraic sum of these results is the net work performed. Dividing these areas by their respective lengths, we obtain the (M. E. P.) mean pressures for each event of the stroke, for which a proper place is provided on the blank form No. 3.

The external work expressed in foot pounds is obtained by taking the product of the area of the piston in square inches into the distance, into the M. E. P. for that event and for each stroke, this was multiplied by 100, thus making the unit 100 strokes instead of one, to avoid small decimals. These were placed in the proper place on Form 3, and reduced to B. T. U. by dividing by Rowland's equivalent, 778.

The remaining portion of Form 3 is filled by reference to a standard steam-table and the quantities arranged so that they can be referred to by using the symbols as given on the sides with subscripts as given at the head of the columns.

Form 4 gives average measurement, dimensions of engine, and symbols used. Form 5 gives the methods of calculation used in the application of Hirn's analysis, as already explained. The symbols used are those of Buel's steam tables, which Professor Thurston has republished in his work on *Engine and Boiler Trials*, and which was convenient for our use in the Mechanical Laboratory.

The principle of the analysis has already been explained, and an excellent exposition will be found in the work on *Thermodynamics*, by Professor Peabody; yet, at the risk of being tedious, I will explain some details of the method.

The weight of steam is supplied by weighing feed-water or condensed steam; this was subdivided between head and crank in proportion to the work done at the respective ends of the cylinder, as shown by the indicator cards.

The condensing water was weighed and subdivided in the same manner, thus giving us the value of G in the formula. This division is in some respects an arbitrary one, yet as the work done at the two ends of the cylinder is rarely exactly the same, it seems fair to suppose that the steam consumed is proportional to the work done on either end, although the method of division will probably make very little difference in most cases.

To find the weight of steam in the clearance space M, we need to know its pressure and quality. The pressure is taken from the indicator card, and is already tabulated in Form 3; from this and the known volume for a given pressure, the weight of dry steam filling the clearance space at the instant of admission can be found.

The heat supplied is evidently equal to $M(XL + S)$, in which X is the quality of entering steam, S the heat of the liquid, L the latent heat corresponding to the entering pressure, as on Form 3. The heat in the steam in the clearance would be found in a similar way, if we knew its quality, which in this case we did know, by the calorimeter reading, to be slightly superheated at the end of compression. At the best there is some doubt about the accuracy of this determination for quality and farther the percentage of moisture, while it may be a larger percentage of weight, is always a small percentage of volume, it will be much more accurate to ascertain the heat existing at intermediate points from the volume rather than the weight; by consulting Form 5 it will be seen that this method is the one pursued. The steam was assumed to be dry and saturated in the clearance space, which agrees very well with the actual determination.

A check on the numerical work is found by the agreement of the values for D and D' at the bottom of the form. These results are in either case the difference between the heat supplied the engine and that thrown off in the exhaust—in other words, radiation-loss and leakage, etc.

Form 6 is the summary of the preceding forms, and also shows what the quality of steam in various positions in the cylinder must have been in order to harmonize with the heat distribution, as shown in Form 5.

The method of computing the heat is the ordinary calorimetric formula. Weight $(XL + S) =$ heat in B. T. U. The external and internal heat is given for several events of the stroke on Form 5, the corresponding temperatures, pressures and heat of evaporation are given on Form 3; the weight during admission and compression is represented by M and M_0 regardless of the quality. At the beginning and end of compression the weight is equal to that filling the clearance space at the beginning of admission, or is equal to M_0. Solving these various equations for X gives the results shown on Form 6.

$$X = \frac{\frac{\text{Total heat}}{\text{Weight}} - S}{L}$$

In case the work of expansion is not considered, the divisor should be I instead of L. In many cases the quality is more conveniently found by dividing the weight of dry steam by its actual weight. The weight of dry steam is found, in any case, by dividing the volume by the specific volume of one pound.

Thus in symbols:

$$X = \frac{V_0 + V}{(M + M_0)\,C}$$

In which $V_0 + V$ equals total volume of cylinder to point under consideration; C equals number of cubic feet to one pound of steam for the given pressure; M and M_0 as before.

CALORIMETRIC MEASUREMENTS OF THE QUALITY OF STEAM DURING COMPRESSION.

The attempt to measure the quality of the steam during compression was made as follows: A throttling calorimeter of the form shown in the cut, Fig. 3, was connected directly to the cylinder-head, with a whistle valve intermediate, which was arranged as is usual with such valves, with a lever for opening and a spring for closing. The opening lever was modified by the addition of a second lever, thus virtually making a compound lever, arranged so that a very slight motion of the first lever was sufficient to fully open the valve. The lever was connected by a wire to a rod, moved by the reducing motion of the engine, by a cam which was adjustable and capable of being set so that the calorimeter valve could be opened at any required point of the stroke. A second cam could be set to release it at any instant, in which case the rod and valve actuated by springs closed instantaneously. The principal part of this ingenious mechanism was designed by Mr. C. L. Stanton, one of the mechanicians and instructors in the

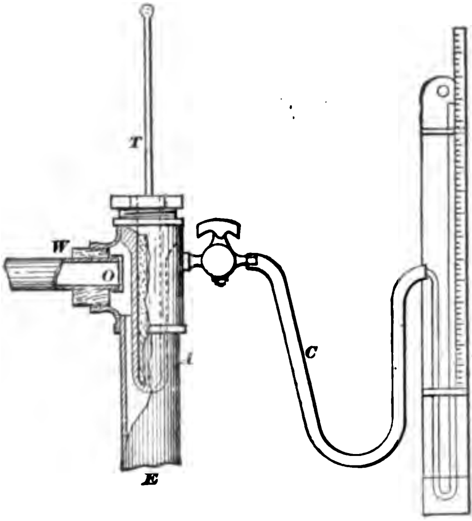


Fig. 3.

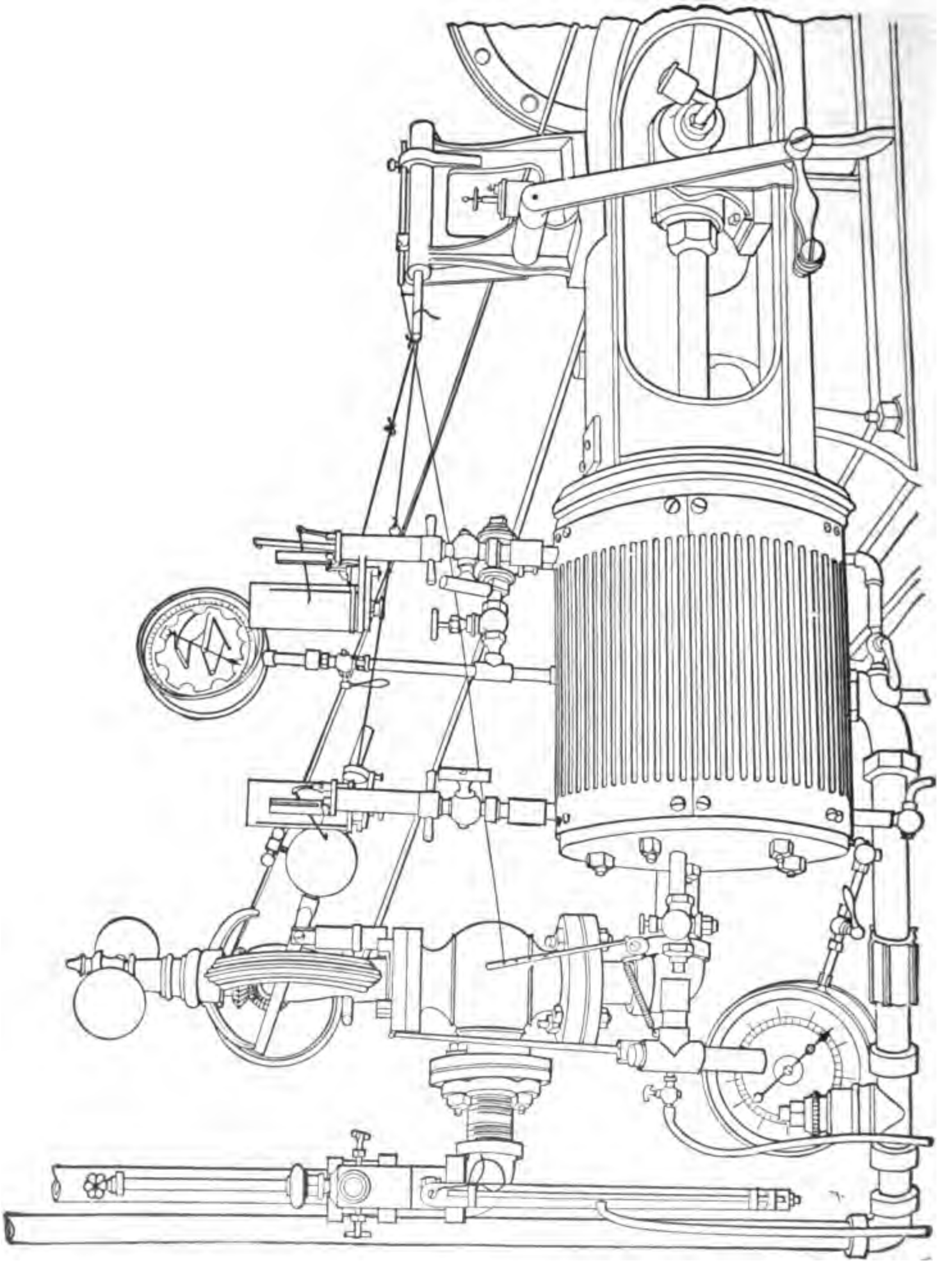


Fig. 4.

Sibley College shops. The cut, Fig. 4, shows the apparatus complete and in working order, except for the lagging which was around it when in use. By referring to the indicator diagram, Fig. 1, it is seen that a very small portion of the compression line lies above that of the atmosphere, and that the calorimeter could discharge into the air only during the time that the piston was passing from *x* to *w*. As the engine made about 200 revolutions per minute, this practically amounted to an instaneous opening occuring 200 times per minute. Great pains were taken to see that the calorimeter valve opened and closed at the proper instant, and that it was tight when closed. So far as could be determined, this action was perfect, the strong springs drawing the valve closed, the instant the trigger was released, with the rapidity of a gun-lock. Now, as to the results: We found that it took a long time, frequently an hour, for the thermometer in this calorimeter to reach its maximum temperature, but that, except in a few cases (some thirty trials being made), this thermometer showed either slightly superheated steam, or steam very nearly saturated. The pressure of the steam was calculated as the average of that shown by the indicator diagram for the time the valve was open.

There was a throttling calorimeter attached to the steam-chest in order to measure the quality of the entering steam. The distance between the two calorimeters was not over 18 inches. Both were lagged and in similar conditions, yet the thermometer in the one on the cylinder, and open only during compression, would often attain a reading 30 or more degrees higher, and invariably indicated 2% to 3% less moisture. Thus in the trial already presented (see Form 1), this thermometer read 258° when the thermometer in the other calorimeter read only 216°.

It seems hardly probable or possible that the maximum reading of the thermometer opened for so short an interval could in any event be equal to the temperature of the steam in the interior of the cylinder, yet it will be interesting to compare this with the results of the calculations made on Form 6. In these calculations it was usual to assume the steam filling the clearance space as dry and saturated, as explained previously, but in this particular trial the calorimetric determination, as made by observation, was substituted.

This investigation seems to indicate that Zeuner was correct in regard to many, perhaps all, of his statements regarding the quality of the steam in the cylinder, but that the error in the assumption of dry and saturated steam in the clearance space, as usually made in the application of Hirn's analysis, is not a serious one.

THE NEW SIBLEY COLLEGE SCHOOL.

The Sibley College organization is slowly, but we may hope steadily and satisfactorily, approaching its complete form as planned in 1885 and again approved by the Board of Trustee in June, 1890. The declared object of the Trustees at the earlier date, in their reorganization of the college and in placing it on its present basis, was two fold: First, to secure a good undergraduate course of instruction in the recognized higher professional work of mechanical engineering, in substitution for the older "mechanic arts" course or, if practicable, the perfecting both of professional engineering courses and of those less abstruse branches required in the preparation for their peculiar work of officers of engineering establishments, especially as superintendents of works and of departments. The organized college was therefore made a system of "schools of Mechanical Engineering and of the Mechanic Arts." Secondly, it was made the duty of its head to establish "as they may be called for, and as the progress of the University may permit," a system of "advanced schools of special branches of Mechanical Engineering."

The progress of the five years ensuing this reorganization and this definition of the plans and purposes of the Trustees, and of the duties of the head of the college and his staff, was seen in the gradual reconstruction of the scheme of undergraduate work, as so prescribed. The college grew from an insignificant beginning to a total of about 450 students, crowding the institution to such an extent that time, money, and facilities for instruction were strained to their utmost in taking proper care of the candidates for degrees in engineering; and the originally intended work of development of schools of mechanic arts, as distinguished from those of engineering, was completely checked by the necessity of meeting this first and greatest demand. The plans for graduate and special schools were, for the same reason, deferred in their execution. In June 1890, however, the time had, in the opinion of the Trustees and of the officers of the college, arrived when it would be practicable to begin the higher work, and the organization of the first of the Special Schools of Engineering was authorized by the Board—a "Graduate School of Marine Engineering and Naval Architecture."

Owing to difficulties in finding the right man to assume the principalship, difficulties arising from the very circumstances which make the institution of the school most desirable and important,—a sudden and pressing demand for the services of such men—it was a year before a satisfactorily able and experienced candidate was found. The recent appointment of Professor Durand to this important office has at last set the enterprise on its feet, and the beginning of a new and most gratifying period of its existence, for the University as well as for the college, is thus effected. Although long deferred, this commencement of the higher work of the college as directed five years ago by the Board of Trustees, may be at least hoped to prove to be the initiation of one of the noblest of the many great plans in hand for the useful development of the University and the enhancement of its reputation for efficiency in the highest, as well as the lowest, of its departments of work. We are permitted to make the following extract from the report of the Director of the college, June 1891, portions of which report, such as have most public interest, have been published in *The Academy* for September:

"The quality of the student body in Sibley College is steadily improving in both thoroughness of preparation and in excellence of work after entrance. The proportion dropped from the University during the current year has been very much smaller than is usual in technical schools, and smaller than in any previous year. This is certainly not due to less difficulty in the course of instruction.

"Graduate work in Sibley College is progressing steadily and most satisfactorily. For the first time in the history of the College, there have been, this last year, two Fellowships assigned to students, candidates for advanced degrees in Mechanical Engineering, one in the regular line of general work, the other in the special branch, Electrical Engineering; and both of these cases have illustrated the advantages to accrue to the college, and to the University as well, by the assignment of a liberal allowance for Fellowships in this department. Not only these gentlemen, however, but other candidates for the higher degree, have been doing admirable work in research, and in the solving most important problems, from both the scientific and the professional point of view."

"The number of students taking graduate work, and the number coming from other colleges to secure the advantages in which Cornell is beginning to be considered as exceptionally rich, is now constantly and almost embarrassingly increasing. It is also becoming more and more usual for young men, whose time and means permit, to take, first, one of the general courses, and thus to secure a liberal education, before entering into the professional school. This last plan is most satisfactory and every possible means is taken to encourage the custom. Professional training is not the equivalent of a liberal education."

It was further stated that the time having apparently come for such a movement, that the Trustees should authorize the preparation for the organization of the long proposed special schools of engineering, "possibly within the next five years; two of which it was thought could be arranged at little cost and with large benefit to the University and to the State;—those of Railway and of Marine Engineering, the two great branches of Mechanical Engineering and construction which seemed most needed by the country, and least well provided. One was authorized—that of Marine Engineering and Naval Architecture. This was deemed desirable, especially, though perhaps not so urgently demanded by the country at large as the second and others, because of the fact that the impending loss of the naval officer hitherto detailed by the general government would cripple us in one of our most important branches of college work, already established and in successful operation.

"The original plan involved the organization of four of these schools, and it was considered best to propose the establishment of this school at once, as being likely to demand no special outlay, except for salaries; and even those being, in part, balanced by the assumption, by those receiving them, of duties which would otherwise require the employment of instructors."

A MANUAL OF THE STEAM-ENGINE.

Part I. Structure and Theory.

BY ROBERT H. THURSTON, A.M., LL.D., DR. ENG'G.

Students of the "Steam Engine" as a heat engine, have felt the need of a scientific treatise which should embody, as well as the thermodynamical theory, the results of modern research and the application of thermodynamics to the theory of the engine in harmony with modern practice.

The first attempt to supply this demand was made by the celebrated engineer W. J. Rankine, also a little later by the German physicist Clausius. These efforts resulted in the production of two treatises, "The Steam Engine" by Rankine and "Thermodynamics," by Clausius, both of which are classical works, and have formed the basis in a large measure of every scientific book on the subject written in recent years. The work of Rankine, first published in 1859, although now on the fourteenth edition, is obscure in many places, and difficult even to the most accomplished mathematician, besides many of the theories advanced are now known to be erroneous, and little or nothing is given of modern methods of research. The work of Clausius is a finished and elegant treatise, from a mathematical standpoint, but of little value to the engineer, as the application of the pure science of thermodynamics is badly and in many cases erroneously made. All the scientific works on the steam engine that have appeared in recent times have been devoted to special forms of the engine, to special subjects, or to improved methods of research. Many of these works are excellent, but from the days of Rankine to the recent work of Dr. Thurston, no general scientific treatise on the subject has been produced.

It is thus seen that this work occupies a special field, and to those who know of the success of the author, as a writer, and as a professor in charge of the most extensive school of Mechanical Engineering in the world, there is no doubt but that the field will be well filled, and that this work, which represents the labor of many years, will be appreciated by engineers and students for generations yet to come.

The entire work is to consist of two Parts. Part I, now issued, devoted to the Structure and Theory, consists of seven chapters, as follows: Chapter I, History; Chapter II, Structure of the Modern Engine; Chapter III, Philosophy; Chapter IV, Thermodynamics of Gases and Vapors; Chapter V, Theory; Chapter VI, Compounding, Jacketing, Superheating; Chapter VII, Efficiencies of the Steam Engine. Appendix containing a great variety of tables, useful to the student and the designer of the steam engine.

Part II, in press, relates to the design, construction, and operation, and is to discuss those questions of special interest to the designer, proprietor, and operator of the engine.

The limited space at our command does not admit an extended description of the work, nor a discussion of its especial merits; but attention is called to the following features as being of special interest to students of the steam engine:

The work consists of 861 pages, of which nearly 100 are devoted to tables, and contains 168 illustrations. It is in fact literally filled with choice illustrations of the master-pieces of American engineers.

The frontispiece of the first volume is the experimental engine in Owens College, Manchester, England; that of the second volume will be the experimental engine now in process of erection at Sibley College.

Among the engravings are found views of all classes of engines, Marine, Locomotive, Portable, Stationary, Fire, Agricultural and Pumping, and in addition, views showing the special types built by the most noted makers of this country.

Despite the attractiveness of the historical and structural portions of the volume, this part will be principally sought for by the student, because of its clear statement of the philosophy of the engine. In this respect the work stands without a rival. In no other volume will the student find a complete treatise, first on pure thermodynamics, second an application to the steam engine by the general methods of Rankine and Clausius, and third a treatise showing the modifications necessary in the application of thermodynamical methods to the real engine. The statements being clear, the students will have no difficulty in comprehending the mathematical processes involved, and they should obtain a clear conception of the relation of the ideal to the real engine.

The results of recent investigations and the modification of earlier theories are noted. The experimental theory of Hirn is explained, methods of application are given, and finally there is presented the application of modern investigation to a method of ascertaining the maximum efficiencies of the Steam Engine.

FACULTY CHANGES.

Since the close of the last college year the instructing body of Sibley College has been very much enlarged. The new-comers are all preeminently fitted to perform their duties satisfactorily, and indeed the engineering department of the University is to-day provided with a corps of instructors that augurs a very bright future.

W. F. DURAND,

Professor of Marine Engineering and Naval Architecture.

Professor Durand graduated from the Naval Academy (Engineering Course) in the class of '80. He was one of the two members of the class who received the Pro Forma reccommendation of the Board for appointment as Assistant Naval Constructor. After his graduation Professor Durand remained in the naval service for seven years longer, during which he was on detail at Lafayette College for two years. He also served short details at the Worcester Polytechnic Institute, in the draughting room at the Navy Department, and at the Morgan Iron Works on duty connected with the construction of the engines for the first of the "New Navy." The remainder of his naval service was in sea duty. After his resignation from the Navy he took charge of the Mechanical Department of the Michigan Agricultural College, where he remained until last June, when he was appointed Professor of Mechanical Engineering at Purdue University; but he preferred the position at Cornell. While in college he gave attention to mathematics and mathematico-physical work in addition to engineering work proper. With this preparation and the general training he has had, Professor Durand will doubtless prove to be a very valuable instructor and thoroughly qualified for his work here.

JOHN M. BARR,

Senior Assistant in the Department of Machine Design and Assistant Professor of Mechanical Engineering.

Prof. Barr comes from the University of Minnesota where he was Professor of Mechanical Engineering. He is a graduate of that University (B. M. E., '83; M. E. and M. S. later) and M. M. E. Cornell '89. He was engaged in business for some time after his graduation, but finally returned to accept a position as instructor in Mechanical Engineering at his own college, where he remained three years After spending a year at Cornell in graduate work in engineering, he again took up his work at the University of Minnesota as Assistant Professor of Mechanical Engineering, and for the past year has held the position of Professor in the same department. Professor Barr's practical experience has included work in the machine shop; the operation of stationary engines; several years of work in wood working and cabinet making; some months at Stillwater, Minn., constructing a system of sewerage; over a year in the office of the resident mechanical engineer at the Calumet and Hecla mines; and sixteen months as a superintendent of the Lake Superior Iron Works, building mining machinery; whence he returned to the

University as Instructor. There Professor Barr has given instruction in the shops, which he practically organized and constructed; in drawing, laboratory and experimental work, kinematics and in mechanics. He is an admirable man, talented and earnest, with ability in the lines of work which he is to assume.

JAMES WISEMAN,

Instructor in Mechanical Engineering and Foreman of the machine shop.

Mr. Wiseman was educated in the city schools of Glasgow, Scotland, where he was also apprenticed for the engineer's trade to one of the large engine and ship building firms, with which he served his time of five years. He has had experience as second engineer on the steamboat Rhonė, and as chief engineer on the steamships Virginia, Schillizzi, Solway, Kaiature, and Oakdale. His last cruise was as chief engineer of the Athabasca, which was built in Glasgow for the Lake Superior trade of the Canadian Pacific R. R. The vessel was cut into two parts and towed through the Welland Canal. His first experience, as an Instructor, was had at the Michigan Agricultural College, where he was Instructor in charge of the machine shop and chief engineer. After serving for three years in this position, he resigned to accept a position as Inspector of boilers and machinery for the American Steam Boiler Insurance Co., with headquarters at Chicago. Mr. Wiseman has, during the two years of his connection with this company, inspected over 1500 boilers, a great many steam engines and other machines. He has been successful in all positions he has held in the past, and much is expected of him at Cornell.

J. S. REID,

Instructor in Mechanical Drawing and Designing.

It was with Wm. Smith & Sons, of Glasgow, Scotland, that Mr. Reid received his early mechanical training. This firm built sugar machinery, marine engines, etc. From there Mr. Reid went to the locomotive works of Barclays & Co., of Kilmarnock, Ayershire, where he remained until about eight years ago, when he came over to America. Since that time he has been employed in the drafting rooms of the Hinckley Locomotive Works at Boston, the Schenectady Locomotive Works, and the New York Locomotive Works at Rome. From the last named place Mr. Reid has come to Cornell. He possesses all the experience and knowledge necessary for the position he now occupies and will no doubt be a very efficient instructor.

C. L. STANTON,

Instructor in Mechanic Arts.

Mr. Stanton spent his early days at Ithaca, where he also served an apprenticeship with Reynolds & Laing. From there he went to Philadelphia where he worked at various establishments, among them Sellers & Co., and the Havermeyer Sugar Refinery. Leaving that city, he was employed as an engineer on the old City of Paris, the Lord Clive, and the Atlas. Mr. Stanton has been employed in some of the principal shops of the country. He is a thoroughly practical man and well fitted for his new position.

RICHARD HISCOCK,

Chief Engineer and Instructor in Practical Engineering, has had an extended experience as an engineer. He formerly lived in New York, but more recently in the West, and comes well recommended.

OREN G. HEILMAN,

Instructor in the Mechanical Laboratory, hardly needs introduction or commendation. As a student of Cornell in last year's graduating class, he is well known to every man in the three upper classes, and all wish him success in his chosen vocation.

THE NEW LIGHTING SYSTEM OF THE ELECTRICAL ENGINEERING DEPARTMENT.

During the past summer there has occurred in the department of Electrical Engineering one of those periods of reorganization and advancement for which the technical departments of Cornell are noted, and which, being of no rare occurrence, have given to those departments the enviable position which they undoubtedly hold among the technological schools of the world. That the readers of the CRANK, both alumni and undergraduate, are interested in these changes, goes without saying; therefore, so clearly as may be consistent with brevity, the improvements and additions occuring to this department during the summer will be noted.

Following the action of the Trustees appropriating money for the purpose, and through the efforts of Professors Thurston and Ryan, there has been designed and put in operation the lighting plant of the University as it now exists, and which it is expected will be extended so as to furnish light for all the important buildings upon the Campus.

We will describe the plant systematically. Beginning at the power-house, there will soon be in operation there a 100 H. P. a 75 H. P. and a 40 H. P. horizontal turbine water-wheel, which by means of two wire rope cables will deliver 200 H. P. to the dynamo room when required. The two larger wheels were furnished by R. D. Wood & Co., of Philadelphia, while the 40 H. P. wheel is that which has furnished power for the shops for a number of years. To supply water for this increase in power, a new dam has been built near the position of the old one, but extending directly across the gorge. The height of the dam is somewhat greater than the old one, so that the total head available is about 45 feet. From the dam a boiler-iron pipe, 5 ft. in diameter, leads to the wheel-house, where the power of the water-wheels is transmitted to a jack-shaft carrying two 11 ft. sheaves, over which run the two wire ropes transmitting power to the dynamo room. At the dynamo room the ropes again pass over 11 ft. sheaves mounted on a 6 in. shaft, just north of the present main shaft. The new 175 H. P. special triple expansion engine, and also the 60 H. P. tandem compound Lansing engine will be available to furnish power to this shaft when required. The Walker Manufacturing Co., of Cleveland, furnish all the equipment for the transmission of power.

To make room for the new experimental engine, the dynamos of the lighting plant have all been moved into a room built at the base of the large Sibley stack. In this new dynamo room are to be found the large No. 12 Edison incandescent dynamo, a Westinghouse arc machine, furnishing current at 1,800 volts; also an alternator of the same make, furnishing current to the incandescent circuit at 1,000 volts. Besides these machines there are in the room the Westinghouse exciter, and the various switches, volt-meters, ammeters, etc., ordinarily found in connection with such a system. The connections are so arranged that it will be possible to throw on and off, at convenience, any of the water-wheels, engines, or dynamos without in any way interfering with the operation of any other portion of the plant.

From the dynamo room the arc lighting circuit extends as last year, but a great change has been made in the incandescent system. Leading from Sibley College to Sage College, to the Library and to Morrill Hall, are laid 9,000 ft. of duplex conductor manufactured by the Standard Underground Cable Co. This conductor is insulated to be worked up to 2,800 volts and its capacity at 2,000 volts is 2,500 lights of 16 cp. each, with but 4% drop in the line at maximum output. The duplex cable was used for this purpose as with the alternating current its two conductors lying side by side neutralize all effects of electrostatic and self induction and also greatly lessens the danger of disruptive discharges in the cable. Of this underground cable, 8,000 ft., leading directly fiom Sibley to Sage, contain No. 6 wire, and a branch of 1,500 ft. to the Library and Morrill Hall, has No. 10 conductor.

In the Library are placed 950 lights, and there is in that building converter capacity for 360 lights which it is expected will be sufficient to light all portions of the building that may be required at any one time. For example, the 360 lights will light the White Library room, the main reading room, the lecture room, and the few lights that may be wanted in the stacks, at the entrance and in the seminary rooms.

It is expected that a storage battery will be placed in the Library building, which will be charged by a synchronous motor and dynamo operated by the same, which will be switched into the circuit at night when the load is light, and during the day the battery will serve to run a book lift and such lights as may be required for ill lighted portions of the building.

In Sage College have been placed 360 lights, and there is converter capacity there for 320 lights, which is in excess of what will be the normal load.

The converters are 40 lighters, operating at 1,000 volts in the primary and 50 volts in the secondary. They are from the National Electric Manufacturidg Co., of Eau Claire, Wis. In all cases the converters have been "banded," a method not often employed owing to the danger of one or more of them having less resistance in its circuit than the others so that it will become overloaded. Before the full load was applied to the system the primary current of each converter was measured by means of a Siemens electro-dynamometer to determine if it was doing its share of the work. Impedance coils were provided to be placed in the circuit of the primary of each converter, but the tests showed so equal a distribution of load among the converters as to make their use unnecessary.

By the use of a "step up" transformer at the dynamo room increasing the voltage in the mains to 2,000 volts and using the duplicate circuit already laid, it will be possible to increase the capacity of the system to four times its present normal duty.

The wiring in both the buildings is concealed except in the laundry at Sage College, where a high grade insulation covers the wires which are strung on porcelain knobs. The Library being a fire proof structure it is wired with Okonite wire "built in," while Sage College, not being of fire proof construction, all wires running *across* joints are placed in interior conduits, and those *between* joints have a high grade insulation and are strung on porcelain knobs. The American Electric Supply Co., of Buffalo, did the wiring in the two buildings.

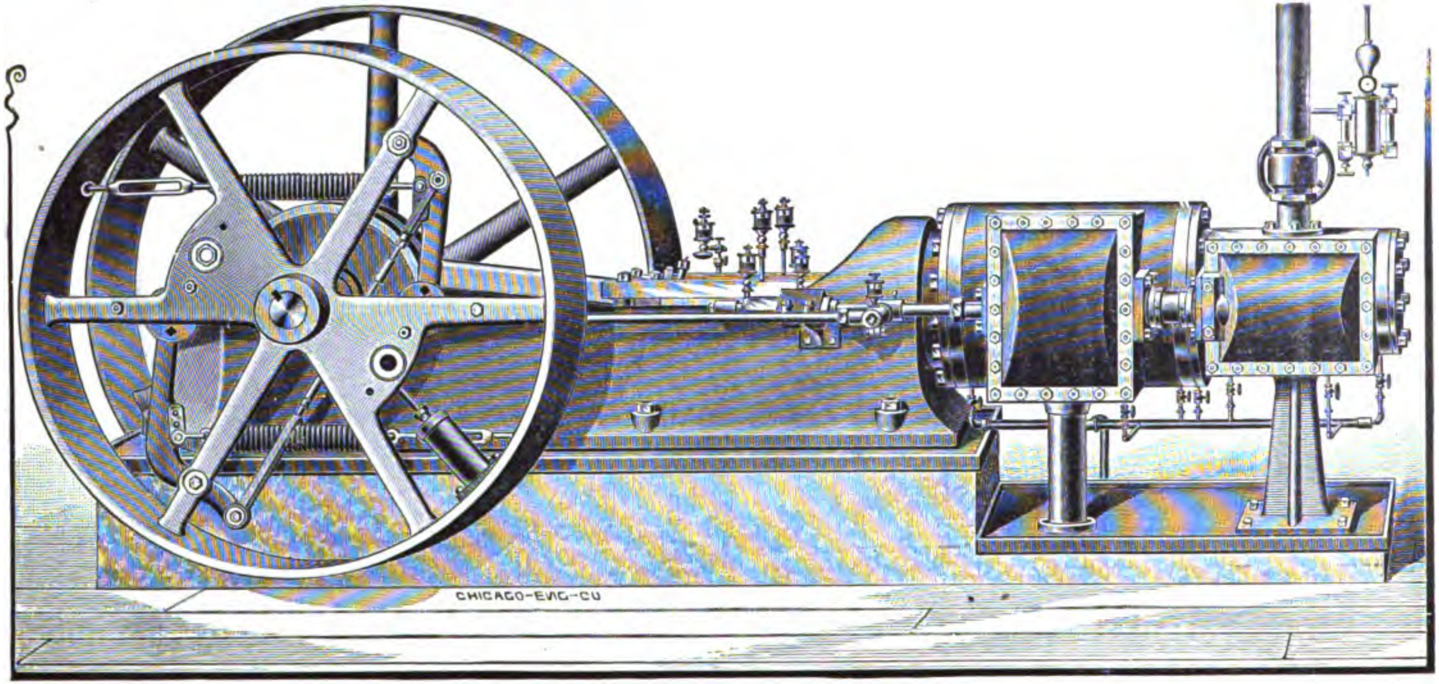
In addition to the incandeseent circuit, in the trenches dug for that system, have been placed 11,000 ft. of Siemens & Halkse arc light conductor, manufactured by the Edison General Electric Co. and another year will see the arc lighting system entirely underground.

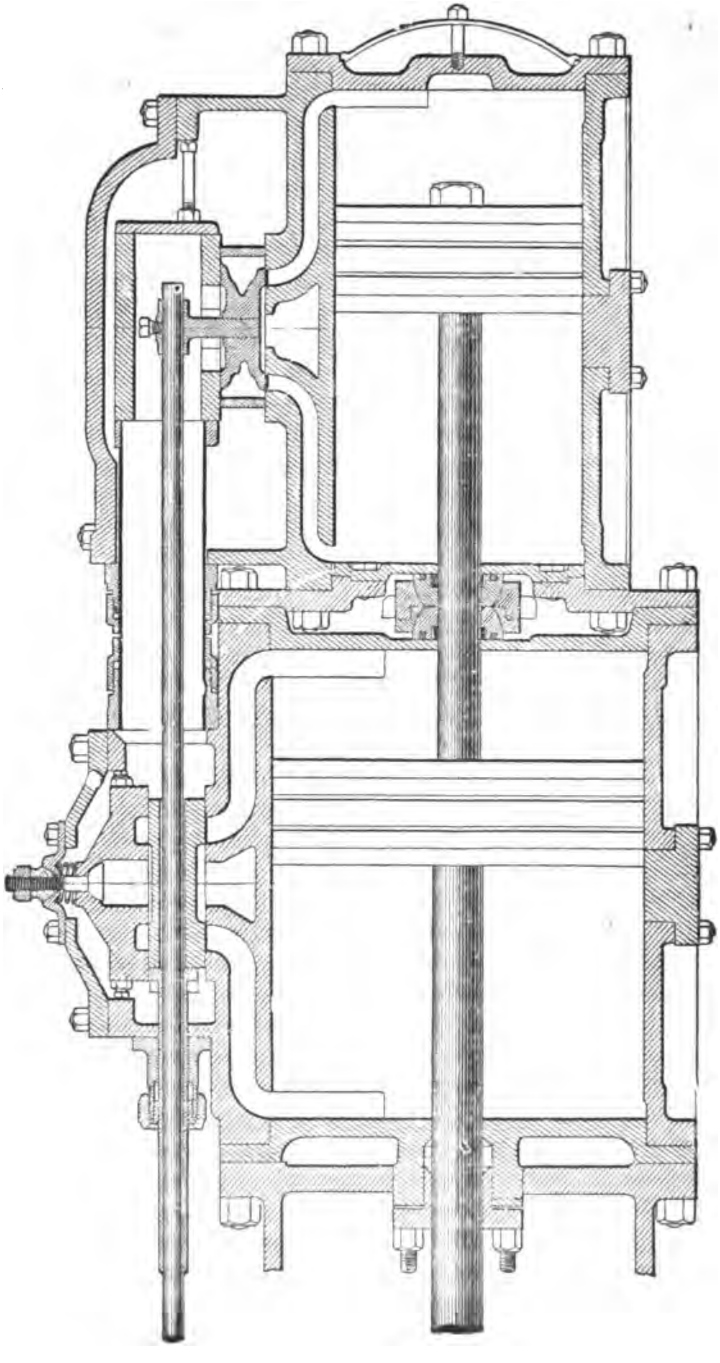
To be used in connection with the new lighting system the following pieces of apparatus have been purchased: a 15 and a 100 ampere Weston direct reading ammeter, a 150 and a 600 volt Weston direct reading voltmeter, a one third microfarad condenser, a multicellular voltmeter reading to 160 volts and a D'Arsonval galvanometer for measuring resistance, and reading to one ten millionth of an ampere.

THE LANSING COMPOUND ENGINE.

During the summer vacation a 60 H. P. tandem compound engine of the centre crank type, built especially for the University by the Lansing Iron and Engine Works, Lansing, Mich., was received by the Mechanical Department. It has been set up in the main engine room, and is to be used for experimental purposes, and for furnishing the required power to the University lighting plant, when water power is not available.

This engine, which is a gift to the University by its builders, is a model of grace, finish and good workmanship. The principal dimensions are as follows: dia. high pressure cyl. 8″; dia. low pressure cyl. 13″; Stroke 12″; revolutions per min. 265. Two fly wheels are provided, one of which contains the governor; their dimensions are: dia. 48″; face 10″; steam pipe 2½″ dia.; exhaust pipe 3″ dia.


CHICAGO-ENG-CO



Referring to Fig. 1, it will be seen that great care has been taken in the distribution of the extra metal in the essential places, making the whole very strong and rigid. It will be noticed that the steam chests are both placed on the same side of the engine, thus allowing the shortest possible connection between them. This, in turn, means the least amount of metallic surface exposed to the steam and consequently the maintenance of condensation at a minimum.

The valve is made in one casting, with a port at each end connecting with the other, as shown in Fig. 3. Over the back of the valve is placed a pressure plate which provides a second valve seat. This arrangement furnishes four openings through which steam can simultaneously flow to the same cylinder port, thus giving a very large port opening with a small travel of the valve, and also a quick opening at the beginning of the stroke, allowing full pressure up to the point of cut off. Another advantage possessed by this valve is that, in case water enters the cylinder with the inflowing steam, the valve can rise from its seat the instant the pressure in the cylinder exceeds that in the steam chest. This releases the water and saves the expense and delay caused by broken cylinder heads, crank pins, boxes, etc.

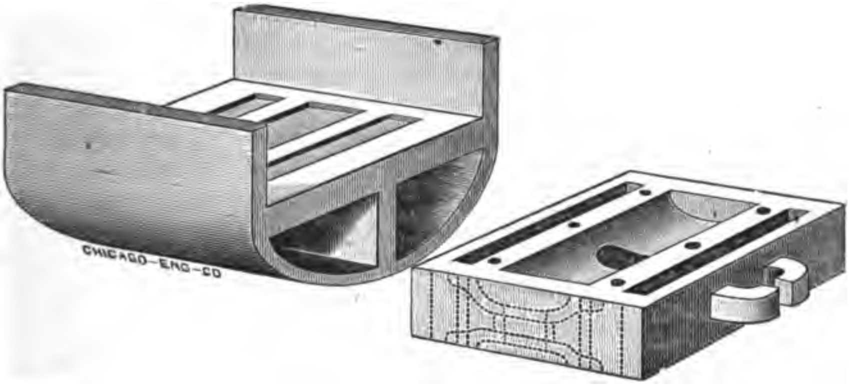


Fig. 3.

The governor is of the fly wheel type and was designed several years ago by Professor R. C. Carpenter. By referring to Fig. 4, it will be seen that this governor is very simple, the eccentric being hung on an arm which allows it to swing across the shaft by means of two levers pivoted to the spider of the wheel. The outer end of each lever carries a weight, while the opposite end is connected by links to the eccentric, so that when the weighted ends are thrown out the eccentric changes its angular advance and throw, thus varying the cut off as already explained. The coil springs and other details are plainly shown in Fig. 4. A novel feature in this governor is, that another agent beside centrifugal force is used to make the governor more sensitive, namely, inertia. This inertia is made use of by pivoting the arms so that when the governor is working the weights are in such a position that a line drawn through their centre of gravity, perpendicular to the radius, will pass to one side of the arm pivot The force due to inertia, when the speed changes, acting nearly along this line, tends to turn the arm about the pivot and thus move the eccentric in the same manner as the centrifugal force but, being the quicker of the two, it gives to the governor a sensitiveness which is almost if not quite impossible to obtain without it. The resultant of these forces would give close regulation if the effects of inertia and friction of parts were taken out of account. The increase of tension on the governor springs would result in producing a sensitive gov-

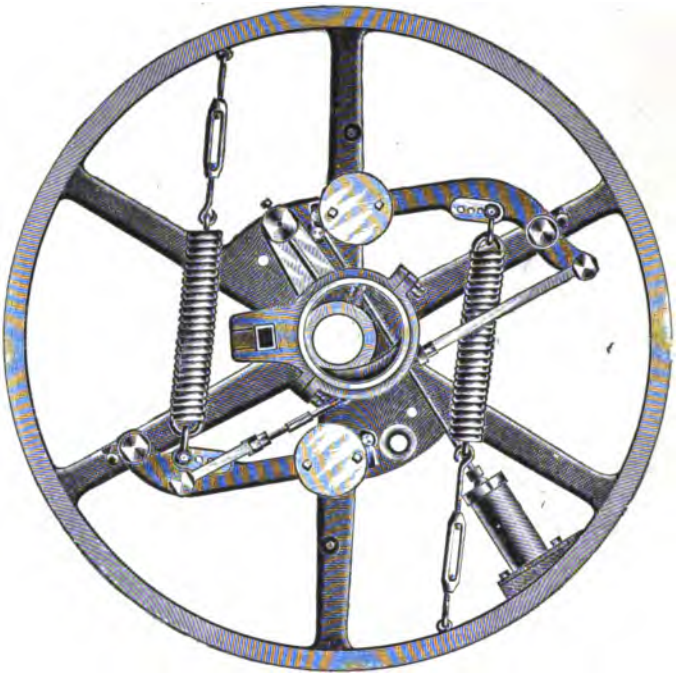


Fig. 4.

ernor, but one at the same time which would oscillate between certain positions producing a motion known to engine builders as "racing." To overcome this and at the same time to allow the governor to act quickly, an air dash pot has its piston attached to one of the weight arms in such a manner that any movement of the weights gives a corresponding movement of its piston. The result is such close regulation that the builders guarantee their engines to regulate within two per cent. from full to no load and under varying steam pressures, providing the latter are sufficient to do the work required.

In connection with the above engine, a belted jet condenser of entirely new design and built from new patterns has been provided, so that the engine can be run condensing or not, as desired. The condenser is also manufactured by the Lansing Engine Works, and is rated by them at 50 H. P. to 100 H. P.

In appearance the engine is strong, compact, simple and perfectly accessible throughout. All bearings are large, with good oiling attachments, insuring smooth running, while ample belt surface and heavy fly wheel prevent the possibility of slippage. The condenser air pump is amply large enough to remove the greatest quantity of water used. It is a double acting pump and is free from all air traps. Its dimensions are: bore 9½"; stroke 7"; revolutions per minute 60 to 70; diameter fly wheel 40"; width of belt 6".

Great credit is due the Lansing Iron and Engine Works for the quality of workmanship and the general excellence of design of the machinery they have been sending to the University.

NON-RESIDENT LECTURERS, 1891-2.

Eckley B. Coxe, Oct. 23; C. J. H. Woodbury, Nov. 6; F. W. Clarke, Nov. 13; Lt.-Col. W. R. King, U. S. A., Dec. 3; R. P. Rothwell, Jan. 7; C. E. E. Emery, Jan. 21; Capt. Henry Metcalfe, U. S. A., Feb. 11; Capt. E. W. Hunt, Feb. 25; E. D. Leavitt, March 10; Geo. H. Babcock, April 14; J. M. Allen, April 28; J. H. Holloway, May 5; Alex. Graham Bell, May 26, and a number of others whose dates are as yet uncertain,—as Mr. E. F. Fenallosa, of the Boston Fine Art Museum, Professor Anthony, W. J. Hamner, C. B. Dudley, Dr. L. Gatling, and a number of distinguished electricians, naval engineers, architects, and other officers and engineers in a variety of special lines of professional practice.

THE CRANK.

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A copy of the first issue of The Crank is sent to every Sibley Student and Alumnus whose address is known. Those who do not wish to subscribe must at once return this copy marked " Refused " to the Post Office or to Andrus & Church's; otherwise the receiver's name will be placed on the regular subscription list.

OUR SIBLEY PAPER.

It is now almost five years since the initial number of THE CRANK was published. During all this time the various boards have, unconsciously perhaps, given us a faithful reproduction of the phenomenal progress made by Sibley College. Last year the number of pages was increased, a new cover was adopted, an Associate Board of Editors added, and a number of exceedingly valuable reports of researches made in the mechanical laboratory were printed. The general quality of the articles that were published in its pages was also of a higher order than ever before.

In order that THE CRANK may continue to be worthy of being called the Sibley Journal of Engineering, it has been found absolutely necessary to change its form to some standard size and to add still more pages. To this end it has been decided to make it an octavo, similar to the Transactions of the various American Engineering Societies. It is the desire of the board of editors to improve the paper in general, to expand its usefulness, and to make it an effective agent for the advancement of the interests of the mechanical and electrical engineering students.

OUR NEW ASSOCIATE EDITOR.

At a meeting of the Board held October 13th, Professor John H. Barr was elected to fill the vacancy caused by the departure of Professor A. W. Smith. The Board cordially welcomes Professor Barr to its membership, and feels well sssured that his efforts will add value and strength to THE CRANK. Professor Barr has already had experience as a journalist, being formerly connected with a technical publication.

MATERIAL RECEIVED FOR THE MARINE ENGINEERING SCHOOL.

It is with pleasure that we acknowledge the receipt, recently, of the following material for the use of Professor Durand and his classes. A complete set of machinery specifications for all new ships for the U. S. Navy designed since 1885. A copy of "Rules of the U. S. Standard Steamship Owners, Builders, and Underwriters Association." A collection of photographs from the Union Iron Works, San Francisco, seventeen in number, showing the U. S. steamship San Francisco in various stages of construction and on her trial trip. One of the latter being an instantaneous view taken with the ship at twenty knots speed. In addition to this, a large amount of material has been promised but not yet received from the Navy Department and several ship yards.

IT WILL BE THE CRANK FOR ANOTHER YEAR.

At a recent meeting of the Board it was decided to change the name of THE CRANK, to the Sibley Journal of Engineering, the change to take effect next Fall. The new title is fully as suggestive as THE CRANK, but lacks that embarrasing ambiguity which often results from the use of the present title. It is, furthermore, a name that, while adding dignity, definitely states the purposes of this paper. A new name has come to be as necessary as it is desirable, and assuredly an appropriate and eminently descriptive title has been selected.

RESIGNATIONS FROM THE FACULTY.

Since the close of the last term there have been an unusual number of resignations presented to the Faculty. In our Commencement issue we announced the acceptance by Prof. A. W. Smith of a Professorship at the University of Wisconsin. Prof. A. B. Canaga, having reached the limit of time allowed by the government, was ordered elsewhere. Prof. C. B. Wing, who represented the Civil Engineering Department in THE CRANK last year, has accepted a full Professorship at the Michigan Agricultural College. Instructor G. W. Bissell, one of the founders of THE CRANK, has gone to the Iowa State College. Mr. George D. Shepardson, formerly Instructor in Physics, has taken the chair of Electrical Engineering at the University of Minnesota. Mr. W. M. Towle, who was foreman of the Machine Shop, has been appointed Superintendent of the Mansfield Machine Co., of Mansfield, O. The last resignation was that of Mr. L. F. Chesebrough, he having accepted a very good position as Mechanician for the University of California.

We announce these resignations with regret, as they were all valuable men, and all of them were very highly respected. They all go to accept excellent positions, bearing with them the good wishes of their friends, and we take this opportunity to congratulate them on their advancement.

REPORT OF THE BUREAU OF STEAM ENGINEERING.

The *Report of the Chief of the Bureau of Steam Engineering* of the Navy Department has appeared in print, dated Oct. 15, 1890. It is most interesting and instructive, and accompanying it are the plans of the new ships designed by the Bureau for the "new navy." These are six in number and demand machinery of an aggregate of over 80,000 horse-power. Three are battle-ships of 9,000 tons displacement, one armored cruiser, one a "protected" cruiser, and one is the already famous "Ammen ram" for harbor defense. Much work has also been done on repairs and in designing new boilers for old ships. Many of the sheets of plans and all the specifications have been sent to Sibley College, to the Director, as an old navy officer, and are available for use in the work of graduate schools and students. In several cases these plans have been subtituted for those of the proposing contractors, as being on the whole the best.

We notice among the recommendations of the report, one for the erection of a 600-ton testing machine, to be used in testing the parts of engines, full size, instead of by sample of their material, as now customary and unavoidable. One of the most important and interesting parts of the document is that in which the personnel of the U. S. N. Engineering Corps is referred to. The corps is now reduced to about 200 in number, and, under existing provisions of law, will be brought down to 170 if no change is made. Meantime, the building of the new fleet has already created a demand for a larger number than are on the list, and the difficulties, taxations and dangers arising from this restiction of the force are steadily increasing. The Engineer-in-Chief, Mr. Melville, states that the demand is imperative, not only for more officers, but for a much better course of professional instruction. A protest is made against the proposal, made by some non-expert but officious person in high rank, that the duties of the corps at sea and on shore should be separated, and the officers mainly confined to the latter. Experience at sea is regarded by all, as essential to the full development of the talent of the officer now responsible for practically the whole internal economy of the modern war-ship. It is strongly urged that the bill introduced by Senator Butler in the upper house, and by Mr. Bingham in the House of Representatives—Bill No. 5779, S., and 8794 H. R.- be passed. This bill provides for a proper course of instruction of cadet engineers at the Naval Academy, and also for the admission to the regular service, as has been done in some cases, in earlier years, and with great success, of graduates of the civil technical schools of the country on passing suitable examinations. The Engineer-in-Chief considers this bill a most promising means of promoting its purposes, and of the improvement of technical education throughout the country as well. The need of officers for the torpedo-service alone would justify a greater extension of the corps than is called for by the Chief of Bureau. The requirements in the engineer's crew of enlisted men and petty officers are no less imperative than among the commissioned officers. The attempt to work an enormously increased fleet with a corps of officers and men provided for the most insignificant navy that a great nation ever ventured to support is likely to prove a disastrous failure, and loss of property and lives may result, such as will far more than compensate the petty economy gained through such ignorance and indifference on the part of legislators and officials, and which has astounded everyone familiar with the subject.

About fifty sheets of working drawings accompany the report, which is on the whole, though brief, rich in valuable information to every engineer, whatever his especial line of work. Applications for it should be made through members of Congress, or to the Bureau from which it issues.

CRANK SHAFTS.

NOTICE.—The position of Editor-at-Large for the present year must be filled by competition from among Specials and Resident Graduates before November 15th. All articles must be received by the CRANK board by the 10th, signed by a nom-de-plume and accompanied by a sealed envelope containing full name and address of the writer.

—The books of the Sibley College Library have been removed to the new Library Building.

—The new cut on the title page was reproduced from a drawing made by Prof. H. D. Williams.

—The June issue of THE CRANK was published too late for distribution in the city, most of the students having gone home. Subscribers can obtain copies by calling for them at Andrus & Church's book store.

—Arrangements are being made by which the CRANK expects hereafter to publish notes, either of the lectures on Electrical Measurements delivered by Prof. E. L. Nichols, or of the graduate course of lectures by Mr. Merritt on Dynamo-Electrical Machinery.

—During the summer months, Mr. Vanderhoef has issued a set of valuable notes on Foundry Practice. He has paid especial attention to the needs of an amateur, and all technical students who intend to do practical work in the foundry should secure copies. They can be had of Mr. Vanderhoef at a nominal price.

—The new experimental engine from the E. P. Allis Co. is here and the work of preparing a foundation is progressing as rapidly as possible. The engine is of the well known Corliss type, triple expansion, and capable of being run condensing or non-condensing. In a later issue of The Crank, the engine will be fully described.

—About the shops may be seen many evidences of renewed activity in lines of especial importance to the students. The construction of a Lockport pumping engine of the Gaskell type has been nearly completed. Castings are expected in a few days of two engines which are to be finished in the machine shop. Under the excellent supervision of Mr. Wiseman and his assistants, the work is steadily increasing in interest and practical value.

PERSONALS.

'91.

G. M. Brill is with the Solvay Process Co., Syracuse.

C. H. Bierbaum is with the Deering Harvesting Machine Co., at Chicago.

H. A. Benedict is with the Thomson-Houston Electric Co. at Lynn, Mass.

H. B. Clarke is with Henry Aiken, Consulting Mechanical Engineer, at Pittsburgh, Pa.

C. L. Cory, M.M.E., after spending a summer in designing engines and machinery at his home at Lafayette, Ind., with Messrs. Cory & Sons, has gone to the Highland Park College, DesMoines, Iowa, to take charge of the classes in Mechanical Engineering and Electricity.

R. E. Danforth is with the Buffalo electric street railway.

H. W. Hibbard is at Altoona, Pa., in the draughting rooms of the Pennsylvania Railroad.

O. G. Heilman has been appointed an Instructor in the Experimental Laboratory of Sibley College.

J. L. Hall, who was last year editor-in-chief of The Crank, is engaged in electrical work at New York City.

F. C. Perkins is acting as European correspondent for several papers. He is at present in Frankfort, Germany.

H. D. Stewart is the pioneer in Dr. Thurston's new course in Mining Engineering.

W. C. Shapleigh passed the summer in Norway. He is now with the Holly Manufacturing Co., of Lockport, N. Y.

Frank J. Tone is with the Thomson-Houston Electric Co., at Pittsburgh, Pa.

H. G. Van Everen is with the Sheffield Velocipede Co., at Three Rivers, Mich.

CURRENT EVENTS.

The formal transfer to the University of the new Library building by Hon. H. W. Sage, and of the White Library by Ex-President A. D. White, took place on Wednesday, Oct. 7th, at 2.30 p. m. Appropriate addresses were delivered by President Gilman of Johns Hopkins, Hon. Stewart L. Woodford, and Professor M. C. Tyler.

Mrs. Ezra Cornell, widow of the Founder of the University, died at the family residence in Ithaca on Sept. 2nd.

Resolutions were passed by the Senior class on Sept. 30th, abolishing the old custom of rushing and substituting therefor a series of underclass athletic contests, by which to determine class supremacy.

Hon. S. D. Halliday has been chosen trustee of the University in the place of Judge Douglas Boardman, deceased.

The Hare and Hound Club has been reorganized into a Cross Country Club.

The football record is as follows: Bucknell 4, Cornell 0; Cornell 72, Stevens 0; Cornell 12, Syracuse 6.

An attempt to revive the wearing of mortar-boards is being made by the underclassmen.

The Intercollegiate Press Association of New York met at Barnes Hall on Friday, Oct. 16th. Papers were presented by representatives of the college press, and in the evening a banquet was held. Upon its own request, the *Vassar Miscellany* was admitted to membership.

ENGINEERING TESTS AT THE WORLD'S FAIR.

The Council of the American Society of Mechanical Engineers at a meeting held recently, appointed a committee to devise and recommend a series of efficiency tests of engineering appliances. Chas. E. Emery, who served as one of the judges in the Centennial Exhibition on steam engineering appliances, and who was in charge of the steam boiler tests made at that Exhibition, and Professor R. H. Thurston, of Cornell University, who was a commissioner to the Vienna Exposition in 1873 and a member of the jury of the Paris Exposition of 1889, have been appointed upon this committee. Their well-known ability as mechanical experts will be a guarantee that the series of tests they recommend will commend itself to the favor of the profession.

THE CRANK

THE SIBLEY
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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

ECONOMY OF STEAM IN ENGINES AND GENERATORS.

BY SENATOR ECKLEY B. COXE.

Of the many specialists who from time to time appear before the Sibley College students, there is none more popular than Eckley B. Coxe, and the CRANK regrets that it is unable to present his lecture verbatim in his charming and inimitable English. Before introducing the lecturer, Doctor Thurston made a few remarks concerning the object of the lectures on various professional subjects delivered here at intervals by non-resident lecturers.

Upon being introduced Mr. Coxe said that he would offer some practical thoughts on economy of steam in engines and generators with particular reference to the experience in the anthracite coal regions of Pennsylvania. There is no place where there is more room to save steam than in the Pennsylvania coal fields, and the operators are beginning to realize what they have been wasting. Waste is bad engineering and also bad morality. The great function of the engineer is to save waste,—of force, material and brain power. Mark Twain claims that if a man has more profanity than is necessary to use comfortably at home, he need not waste it on his younger children, as he can always give it to the poor. This is particularly applicable to engineers who frequently have a surplus of some material which has a future value and on that account should not be wasted. It should either be employed or stored up for future use.

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*A Lecture delivered before the Students of Sibley College, Cornell University, October 23, 1891.

The following table serves to illustrate how the coal purchasers are avoiding waste by utilizing the smaller sizes which only a few years ago were considered unfit for use.

30	per c't	Lump, Steamboat & Broken, av. for years 1882 & 1883,	9,300,000
55	"	Egg, Stove & Nut, average for years 1882 & 1883,	17,050,000
15	"	Pea, Buckwheat & Culm, av. for years 1882 & 1883,	4,650,000
100	"		31,000,000
22	"	Lump, Steamboat & Broken, av. for years 1889 & 1890,	7,838,600
49½	"	Egg, Stove & Nut, average for years 1889 & 1890,	17,636,850
28½	"	Pea, Buckwheat & Culm, av. for years 1889 & 1890,	10,154,550
100	"		35,630,000

Last year there were 1,000,000 tons less than formerly of the prepared sizes. The increase was in the small sizes that had been thrown away before that time, and has been brought about by the attention and care that each individual has given to the method of preparing, screening, sizing and purifying the coal.

The problem to be solved in each particular case, when you take up the questions in practical life, is not a simple one. Your first opinion is likely to be wrong unless you have studied the question thoroughly; for as you examine the matter more carefully you will find more and more circumstances which will tend to modify your opinion. In "Fables out of the World" there is a story concerning a farmer who had two turkeys, one of which was wise and the other foolish. The first would not eat corn but the second eat the corn for both and fattened more and more. Thanksgiving Day drew near and the wise turkey became thinner and thinner, while the foolish one was continually growing fatter. On Thanksgiving morning the farmer upon looking over his turkeys said that it did not pay to fatten the thin one, so he killed it and, after filling its craw with shot, took it to the market and sold it by the pound, while he kept the fat one for his Christmas dinner. You are not always able to tell at a glance what is the best thing to do. Decide what to do and don't do it for awhile. Then start in doing it quietly and in such a way that if you do not succeed you can get back without being found out. The wise engineer improves his plant slowly and continuously, doing the best he can with the money and resources at his command. On the other hand, the foolish engineer tears down everything, rebuilding and renovating to make what he considers improvements, and as a result he ruins his company or frightens his capitalist. To illustrate, our coal company has now about 200 boilers in operation and although much better systems might be found, yet before throwing out the old boilers we must consider (1) cost of new ones, (2) the delay of work, (3) after having installed the new system, there would probably be a better one found, whereupon consistency would require us to begin over again, (4) such work should be done out of current profits.

Anthracite coal differs from most of the mineral fuels in the fact of its being perfectly solid and containing practically no volatile matter. It can only burn at the surface; hence it is necessary to have a good draught around the lumps. This can only be accomplished when the coal is well sized, otherwise the small lumps stop up the passages between the large ones and so diminish the draft. Neither does anthracite coal coke, or get spongy like bituminous. The consumption of anthracite coal began with the large sizes, chestnut coal being thrown away in the early days of the coal trade. First chestnut coal was utilized, then pea, then No. 2 and No. 3 buckwheat. The increasing quantity of dust in small coals renders them difficult of consumption, in consequence of the small holes that are necessary in the grate for burning them. Of course the same amount of carbon is in the coal notwithstanding the size. Iron pyrites occurs only in small fragments, and consequently, is found principally in the small coals, and the percentage apparently increases with the smallness of the coal. In many cases the slate which occurs interstratified with, under or above the veins is very much more friable than the coal, breaking up into small fragments more easily, and in this way increasing the relative proportion. There is also a greater percentage of slate-coal broken up, that is to say, if you have to break up anything you break up your dirty coal first and consequently you get more dirt in the small coal. The perfection of jigging is directly proportional to the regularity of the coal, in other words, the more regular the size, the more perfect the jigging will be. If you undertake to jig Nos. 1, 2, and 3 buckwheat together, you will get a very much less perfect separation than if you jig each one of them separately. This is especially the case in the feldspar jigs, where the stroke and the number of strokes are very important elements, and also the size of the feldspar and of the perforations at the bottom of the jig. It is also pretty clearly proved that those jigs which will work best on sizes including pea and larger, are not as well adapted to the smaller coals ; and I believe that the converse holds true.

In the beginning very little attempt was made to economize coal in the construction of boilers, the object being to get the most steam from a given expenditure of money on the plant, without regard to the amount of coal used. The boilers were generally simple cylinder boilers, almost always too short and with a common grate bar. One stack was generally erected and additional boilers added to the one stack, thus cutting off draught. The first progress consisted in lengthening the boilers and erecting a separate stack (generally old boilers) for each set. This was followed by the introduction of a forced draught. Then it was found desirable to enlarge the grate surface, to make it wider and deeper so as to use smaller coal with the old grate bars. Next, in order to use finer coal, the grates had to be made finer and so the Wootten boiler was frequently adopted. The staircase grate which is much used in Germany is not practicable with anthracite coal owing to the difficulty of getting rid of the ashes. Clinkering on the grate has been avoided by the use of the steam blower. The Bethlehem Iron Works recently had a blower in one of its stacks and it worked well. So I put one on mine and the performance was received with rapturous applause for about three hours ; but when it came to cleaning out we found the grate bars and all were melted together. Then came antomatic dumping bars, such as those of Howe and McClave, and improved grate bars, particularly those of Umholtz and Wren. Feed-water heaters were also placed in the stacks, and water-jackets put around them. That illustrates very clearly how much heat went out through the stack. More attention was therefore paid to the relation between the grate surface and the heating surface. An examination of the temperatures of escaping gases showed them at an average temperature of 940° F. After the introduction of feed-water heaters an increased evaporation of 1.41 to 1 over former practice was secured. Mud drums were also added, and boilers made of large tubes were inserted between the cylinder boilers and the stack.

High class boilers were adopted with high steam pressure, such as the Babcock & Wilcox, which are not practicable, however, where bad water may have to be used. The difficulty, even with the best bars for burning small coal, is that if you make the openings small enough to prevent the fine coal from falling through, you get too little opening for your air and are obliged to burn very slowly. There is considerable waste even then. Fine coal mixed with larger, such as you get from a culm bank, which is generally composed of Nos. 1, 2 and 3 buckwheat and some pea coal, will burn better than the dust by itself, because the larger lumps will generally drop in and stop the holes; but it is a very doubtful question whether the dust does more than increase the quantity of ashes. Complaints of these small coals are almost always made if they contain more than a very small amount of dust. The deterioration of coal on the culm banks varies greatly. Some coal will remain on the culm bank for a good many years without deteriorating very much, others deteriorate very rapidly and often take fire shortly after being dumped.

The utilization of old plants by improving them, instead of tearing them down and building new ones, is worth very careful consideration when the profits do not warrant large expenditures. Although your boilers and engines may not be as good as you would like them to be, nevertheless the knowledge that they are better than they might be, should be of some comfort to you. Furthermore a boiler that would pay magnificently in New York or Philadelphia might not pay at all in the coal regions of Pennsylvania. To-day we can evaporate more water with No. 3 buckwheat than could formerly be done with No. 1. In a recent test we evaporated with No. 3 buckwheat, to which some bituminous coal had been added, 6.54 pounds from and at 212°, and 6.60 or 1% more without the admixture of bituminous coal. No. 3 is the size that will pass through a round hole not less than $\frac{3}{32}''$ or $\frac{1}{16}''$ and not more than $\frac{3}{16}''$ in diameter.

Following the practice of other people we are using Porter-Allen engines, compound condensing pumps and hoisting engines. Attention has also been paid to the covering of the steam pipes. Care is taken to use good sized receivers. It is possible that for the proper combustion of a small anthracite coal the apparatus for managing the draft should involve the combination ascribed by one young dude to another—it should be a combination of "a sucker and a blower." A young engineer should be very careful in talking about what he has done. Don't take it for granted, when you are in consultation with some one, or advising him professionally, that he does not know something of what you are telling him. Perhaps he knows more than you do about the matter. While discussing or showing to anyone, particularly an expert, any work which you have done or propose to do, don't claim to have invented the steam engine or the chimney. In fact, don't claim anything new unless you are absolutely sure that it is so. When you come to be consulting engineers, modesty is the best policy.

FIRE HAZARDS FROM ELECTRICITY.*

BY C. J. H. WOODBURY.

The second lecture of the Sibley College course was given by Mr. C. J. H. Woodbury, of the Boston Manufacturer's Mutual Fire Insurance Co. Mr. Woodbury is the vice president of this company, and to him and the work of his company the manufacturers of New England are indebted for the saving of a large amount of property and the reduction of premiums to the lowest limits, by the application of scientific methods of investigation of causes of loss and methods of removal. Mr. Woodbury has had a thorough scientific training, has performed valuable work in the investigation of the properties of lubricants and in other engineering problems, and now has charge of the laboratory investigations conducted by his company in the determination of risks. His lecture was full of valuable suggestions and rules based upon an experience in this line of work covering a considerable length of time, and was illustrated by numerous examples of apparatus and material spoken of. The following is an abstract:

One of the many innovations arising from the introduction of electric lighting has been the development of a new feature in underwriting, which is the beginning of methods of practice which will in time greatly modify systems of insurance.

There have been two methods of dealing with questions involving the insurance of elements of unusual hazard; the one being that of underwriting pure and simple, estimating the hazard from the best data at hand and charging a rate commensurate with that risk,—the correct principle being that the hazard of the whole is equal to the greatest hazard of any part of the risk.

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* A lecture delivered before the students of Sibley College, Cornell University, November 6, 1891.

The other method has consisted in eliminating the hazard of the more dangerous parts by removing such processes to another building, or at least placing them in a portion of a building where the chances of their imperilling the whole would be controlled by special methods of construction and also by additional fire apparatus; or, in other words, bringing the hazard to conform to the rate of insurance.

The latter method is confined to class insurance of such limited range that the detailed supervision of risks can be within the personal scope of the administration of such insurance companies.

The introduction of electric lighting in this country was followed by numerous fires caused by this new method of illumination. After the disturbance incident to the first scare, careful investigations were made into the subject,—the greatest result of which was the establishment of the opinion that the elements of excessive hazard were not necessarily inherent in such applications of electricity. In other words, such fires were to be classed as preventable fires within the limits of ordinary practical means; and on this basis the rules for electrical installations were first prepared, only to be followed by other rules, drawn up by various parties, to apply to new conditions for the use of electricity for the transmission of power and alternating currents, as well as to improvements in both arc and incandescent lighting.

The electric lighting interests have always and without exception coöperated with the underwriters in these investigations, which indeed could not have reached to successful results had it not been for the indispensable services afforded by the skill of those engaged in this manufacture.

The essentials of safety consist in confining the electricity to its metallic circuits, the prevention of undue arcs in switches and lamps, and the prevention of sparks or carbons falling from arc lamps; but in their applications these precautions are necessarily involved in order to meet all of the complex conditions of the apparatus used in the various applications of dynamo currents.

The danger of fire from dynamo currents is almost entirely due to the diversion of a portion of the electricity from the system, and to the fact that the miscellaneous conductors forming these outside circuits are not adequate to convey the current without undue and dangerous heating. Moisture on an otherwise poor conductor generally plays an important part in such conversions of electricity into heat, because the small trickling of water is readily dissociated and then the resistance at the place is increased to a sufficient amount to cause the electricity to be converted into heat of sufficient temperature to ignite any combustible material in its path.

Rain water, or that from ponds used for a public water supply, is a rather poor conductor, but in passing over whitewash it takes enough salt and lime into solution to become a very fair conductor, and the same applies to water used in washing floors.

About ten years ago I made some experiments upon this matter for the purpose of investigating into the conditions of two fires caused by arc lighting circuits.

From the binding posts of an arc lighting dynamo with forty lights in circuit, two wires about six feet in length were secured one foot apart upon a broad board, thus providing the greatest difference of potential in the circuit, amounting to about two thousand volts, in a place where it was convenient for experiment. The board was washed with a clean mop wet with pure water, but without producing any effect. Then a little salt was thrown into the water, and the water was rapidly dissociated and evaporated, and the board set on fire, not merely on its surface, but well into its interior.

I wish to submit to you some of the principal considerations covering the several conditions of installations, presenting what should be considered as a consensus of the opinions of underwriters and electricians who have made a specialty of questions pertaining to the fire hazard of electricity, and these opinions are mainly based upon the experience of actual fires, or experiments in which conditions of possible hazard have been simulated.

Dynamos, generators, and motors should be considered as machines rather than as merely electrical apparatus. The shafts of the armatures should be provided with journals well suited to maintaining free lubrication and to run without undue heating. The oil pans should be arranged so as to prevent any oil from being spilled on the floor, and moreover the oil should be drawn from these pans so frequently as to prevent any accumulation of oil therein.

The dynamo should rest upon substantial foundations adequate to keep it from jarring, and if used to generate currents at a tension of over 350 volts, there should be a space under the floor, as that is about the only means of preventing the attendants from receiving severe shocks if there should be a ground on the circuit.

Dynamos should be protected from exposure to water, and for this reason it is generally unadvisable to place automatic sprinklers over a dynamo room, as a discharge from any of these might cause a great deal of injury. Each dynamo should be provided with a waterproof cover, which is to be placed over it when not in use.

The use of motors and dynamos for trolley systems of street car propulsion introduces special features which must be provided for. In the present state of the art, the single trolley wire with a return current through the earth is the only feasible means of operating an electric system of street car propulsion; and the question of the extra hazard of the motors must be met by placing the generators in special buildings, and thoroughly protecting the system of overhead wires by suitable guard wires.

One of the more recent applications of electricity for illumination is the use of alternating currents in connection with transformers or converters. This apparatus should be situated in a secure place outside of the buildings, except in case of underground service, when the converter may be put in any convenient place that is dry and does not open into the interior of the building.

Converters should be equipped with safety fuses at the junctions of all feeders and mains, and furthermore the wires of the secondary circuit should be protected against the current of the primary circuit reaching the interior of the building by the use of air or film cut-outs connected with both poles of the wires of the secondary circuit near to the converters, in order that if there should be any direct electrical conductivity from the primary to the secondary circuit, the primary circuit would be grounded at once. These cut-outs are generally adjusted to operate whenever the current reaches a potential of 350 volts.

It is not desirable to permanently ground one of the wires of the secondary circuits, because in such cases the wires have the same fire hazard as if the circuit was furnished with electricity from a dynamo, which would be diverted from the system whenever a second ground occurred; and it should also be borne in mind that the alternating currents tax an insulation more severely than a continuous or even pulsating current, and that as a practical matter the primary circuits of an alternating system conveying currents of high potential are almost always grounded.

Switchboards are a frequent cause of fire, because at these points are concentrated most of the extreme differences of potential due to the system, and arcs are frequently formed in the ordinary use of the switchboards. A switchboard should not be placed against a hollow partition or in any other place where it might readily communicate fire to the building. Thus far slate appears to be the preferable material for the construction of such switchboards, but when such switchboards conduct currents of high potential there is a slight leakage across the slate, and it is necessary that the holes should be bushed with hard rubber or other material. Switchboards should not be made in any event of plain wood surfaces, but whenever the circumstances are such that it is not practicable to use an incombustible material, an open skeleton of wood will best serve the purpose.

Wherever resistance boxes or equalizers are placed, precautions should be taken for the prevention of any accident in case they should become heated. Most of the frames of such apparatus are now made of metal, and asbestos paper is placed behind them if they are secured near to wood.

The lightning arresters should be connected to the earth outside of the building, and gas pipes should not be used in such connections. Water pipes are the best base to which to attach wires from lightning arresters.

It is not surprising that there should be a general opposition to overhead wires, of such a wide spread and determined nature that they would have been placed underground years ago had there been any means which were feasible in every respect. The only reason for this suffrance of overhead wires has been the fact that the uses of electricity have been essential to the needs of the community.

Underground wires are no new thing. In fact, they preceded aerial wires, and nearly strangled the invention of the telegraph; for when the first line was being laid in 1843 between Baltimore and Washington along the line of the Baltimore and Ohio Railway, subject to the conditional consent of the Board of Directors that "the wires should be removed in case that the electric fluid caused any injury to the property of the company," the wires, as a part of Prof. Morse's invention, were covered with an insulation, placed in lead pipes, and for nine miles, from Baltimore to Relay Station, laid underground by means of a special plow invented by Ezra Cornell. This line did not work, and Ezra Cornell made the invention, which expanded the telegraph from an apparatus to a system, by placing the wires overhead attached to insulators at points of support. All must recognize the great work of Edison in his invention of an underground system adapted to his system of electric lighting.

Since that time ingenious inventors have endeavored to devise methods for running the wires underground, without producing anything practical except to a limited extent, and not feasible in any event except in densely populated localities where the patronage is sufficient to permit the excessive expense.

One of the pioneer efforts to devise an underground system fitted to American practice in arc lighting was that of Prof. W. A. Anthony, who laid wires under the Campus at Cornell University in 1878. But I have been informed that this did not stand the deteriorating influences of time, and the drain layer's pick.

As the objection to overhead wires is largely based upon their unsightliness, so, on the other hand, the safety of underground wires is far more an assumption than a reality. The maintenance of insulation from the earth with currents of high electro-motive force seem to be impracticable, even when the material of the conduit, as well as the covering upon the wires, is of high resistance.

In addition to the grounds on the buried wires, which may be the primary cause of difficulties elsewhere, there have been numerous destructive explosions wherever underground wires have been used. These explosions have been generally, and I believe incorrectly, ascribed to leakage of illuminating gas into the conduits. Even if there was such a leakage, there would not be any arc or undue heating of wires causing an ignition of the gas unless there was a connection to earth, and in such a case the explosions would vary in force and only be severe in case of the coincidence of a certain mixture of gas and air.

As these explosions have always been of a violent nature, we must look elsewhere for a cause which will always produce a high detonation ; and this is accounted for by the presence of water in the conduit. Water being readily dissociated by electrolysis into a highly explosive mixture, an explosion would occur whenever the supply of water diminished sufficiently to produce an arc.

It is, however, undoubtedly true that gases from sewage as well as illuminating gas penetrate into conduits, and the lead covering on the insulation of wires in conduits, is in some instances actively attacked from such causes.

It should not be forgotten that the network of wires over the cities has been of great service in robbing the lightning of its dangers, more largely by induction than by dividing the charge and conducting it to earth. It is a fact that injurious effects from lightning in cities have diminished of late years, and, notwithstanding the density of occupation by buildings, they are far less than in the country.

Wires should be carried well above buildings and attached to fixtures rather than directly to the buildings themselves, being placed high enough not to interfere with firemen or others passing over the roofs. They should also be clear of other wires, and protected with dead guard wires whenever there is any possibility that they may fall and come in contact with other wires.

The question of the insulation of such outside wires is far from being a settled one to the extent of actual practice. The greater part of the insulating material on these wires has become so deteriorated as to present but little electrical resistance, and it is necessary to place wires in such a way that the reliance will be upon the freedom from contact with other conductors, rather than upon the insulation itself.

An insulating material upon outside wires should be waterproof and also able to resist the severe and almost continuous abrasion liable to come upon them, and where these wires enter buildings, they should be bent in what is termed a water loop, so that the immediate approach to the building shall be upwards. They should also be provided with a double pole switch capable of being operated from the outside, entirely cutting off all electrical connection with the inside of the building, when so desired

Whenever outside underground service is in use, still greater precautions are necessary at the entrance of the building. It is essential that there should not be any free opening from the cellar of the building to the conduit, and that the insulation of the wires should be maintained at this point and up to some suitable location where a double pole switch can be placed.

The greatest danger from wires outside of buildings is that due to contact with other electrical wires, imposing upon them currents of greater volume than they can withstand, and heating the various parts to such an extent that the injury is not limited to the mere fusion of the coils of such apparatus, but the surrounding combustible material is ignited.

On account of the various widely differing characteristics of these foreign currents, there has not as yet been found any single device which will protect them against injury. These elements of defence have been carried to great perfection by the telephone companies.

The form of apparatus is fourfold in its nature :—First, the ordinary serrated lightning arrester, which is generally able to protect the system by reason of the extent to which the lightning is divided by the numerous wires in its course, and, as has been mentioned before, this lightning is very often inductive in its nature rather than a direct stroke.

Second, the telephones are protected against currents originating from incandescent lighting or power circuits, by means of pieces of easily fusible wire, about four inches in length, inserted in the line of the telephone system. These wires are enclosed in glass tubes, not merely to protect them from injury, but also to prevent any damage being caused by the hot metal of the fuse igniting anything when it is thrown about by the explosive violence which occurs whenever a heavy current melts it.

A similar device consists of a strip of tinfoil rolled up with asbestos paper and forming a part of the circuit, the tinfoil being instantly vaporized by an abnormal current.

Third, for protection against the currents proceeding from arc lighting apparatus and those used for the transmission of power, particularly the overhead trolley system, the most efficient means has been the air cut-out, consisting of two pieces of gas carbon separated a very short distance by means of a thin film of mica containing perforations. One of these pieces of carbon is connected to the earth and the other forms a part of the circuit. Whenever a current on a grounded circuit, having a tension of about 350 volts, passes along the telephone circuit, it leaps the narrow space separating the two carbons and, forming a very short arc, continues to the ground. Small bits of easily fusible metal are inserted in holes in the carbon, and, if the current is maintained for any particular length of time, the metal becomes melted and establishes a conductor of low resistance to the earth. A film cut-out can be used for the same purpose, but in this case is not quite so suitable because of the necessity of readjustment in every case where it is called into operation.

Fourth, another class of accidents is that arising from a cause more difficult to manage, and that is what are known as sneak currents, being generally foreign currents connected with the system by something serving as a shunt of high resistance, so that the current is very small, but yet enough to injure the electro magnets and also to cause fire when they are maintained for a long time, for it should be remembered that the insulating material upon the wires used in electrical apparatus is also a non-conductor of heat, and it is not possible for them to safely conduct as great currents, as if they were not covered with insulation and well exposed to the air, allowing the heat to pass off by radiation instead of becoming cumulative.

The only form of apparatus which has thus far controlled these sneak currents is simply a ball, principally composed of wax and about half an inch in diameter, held against the electro magnet by a strip of spring metal. Whenever the electro magnet becomes warm this ball softens, and the movement of the spring operates a switch which shunts the telephonic apparatus out of circuit.

The method which has been described, however, furnishes the most satisfactory results in actual service, being the outcome of investigations of electricians connected with the telephone companies,—corporations whose interests are far greater than those of any individual, for it should be remembered that the telephone companies own all the apparatus.

The installation of conductors for arc lighting circuits inside of buildings should be made with the utmost care. The use of the high electro motive force for arc lighting imposes conditions of insulation far more severe than those of incandescent lighting. Not only should the wire be covered with an insulation which is waterproof, if there is the least danger of water or dampness reaching the wires, but wires of opposite polarity should be separated at least a foot apart.

The specifications for insulation usually require that it will not fray by friction and will stand a temperature of 150 degrees without softening, and to this should be added that the insulation shall withstand as low a temperature as it will ever be exposed to without cracking.

Whenever wires are run in places liable to dampness, reliance should not be placed on the insulation alone, but the wires should be fastened to glass or porcelain insulators, and wherever wires pass through floors, walls, or partitions, they should be further protected by insulating tubing projecting on both sides. The lightning arresters should be grounded outside of the building, preferably connected to a water pipe.

Inside wiring on incandescent work also requires especial care. All parties are agreed that no wires smaller that 18 Birmingham wire gauge or 16 Brown and Sharpe should be used. These have a nominal capacity of conducting five amperes of current, but the limitation of size of wires depends on their position, as the resistance is converted into heat, and exposed wire will safely carry a greater current than when confined behind mouldings or in tubes, the ordinary ratio of practice being one and two-thirds.

No doubt some of the mishaps attending the use of underground wires have been due to the heat of the wires evaporating volatile matters in the insulating material. On shipboard such wires should be tinned before the insulation is applied, in order to prevent any tendency to corrosion. Whenever wires are laid in moulding, there should be a strip at the back in order to prevent the wire from lying against the wall.

Imbedding of wires in plaster is not generally endorsed; but improvements in insulation will render this more permissible, although in any case such wires are subject to interference caused by contraction and settlement of buildings, and furthermore they cannot be arranged to provide for additions and alterations to an electric plant installed in a building.

Dr. A. F. Mason recently informed me of a contract to install forty-eight and one-half miles of electric lighting wire in a building under a contract guaranteeing the wires to resist cement, lime, and salt found in the materials used in the construction of fire-proof buildings, and to sustain an insulation of one million ohms for one year.

Wires have sometimes been concealed in insulating tubing known as interior conduits. These tubes are placed out of sight in a building, comparable in arrangement to a system of gas pipes. The wires are run through these tubes by inserting a stiff steel tape with a knob at the end, which is easily pushed through any portion of the tubing. Afterwards a line is drawn through, and then in turn the electric wires. These wires can be inserted or withdrawn without disturbance to the system. Such tubes, when made of incombustible waterproof material which is a non-conductor of electricity, can safely be installed in the manner indicated, and svrve a very useful purpose in widening the field of applications for electric lighting.

Fuses should be double pole, mounted on incombustible bases and should be used whenever the diameter of the conductor changes.

Each cut-out should interrupt the passage of the current in excess of the amount to which any portion of the apparatus which it protects is adequate to transmit, and the strip of fusible metal should be marked with the current which it will transmit.

There should not be any joints or fuses or switches in rooms containing inflamable vapors or highly combustible material fine enough to float in the air.

Arc lamps should be provided with globes with tight stands, so that sparks from the carbons shall not reach combustible materials. They should also be provided with some stop which will render every assurance that the lower carbon will not fall in case the usual clamp should not secure it. In addition to the hand switch, they should also have an automatic switch which will shunt the current around the carbons if they should fail to feed properly.

Incandescent lamps are not usually a source of hazard in themselves as directly causing a fire ; yet there are some precautions to be observed, the most important being the prohibition of wrapping the lamp in paper or other material which would retain the heat, because it is possible to ignite easily combustible material in that manner. It is considered that a very serious fire once resulted from this cause.

In damp places the sockets should be rendered waterproof, and wherever there are inflammable vapors the lamps should be protected by glass receivers. When incandescent lamps are attached to gas fixtures, an insulating coupling should be inserted in the gas pipe.

In lighting vessels, when it is necessarry to have lights near the compasses, the effect of the electric current on the compass should be carefully considered, and, whenever an electric wire approaches within six feet of a compass, a wire of opposing polarity should be run parallel to it. I do not feel sure that this distance of six feet should be regarded as the minimum to which this rule should apply, and trust that the matter will receive careful investigation, on account of the importance of any question pertaining to the adjustment of compasses.

In the presence of inflammable vapors there should not be any hand switches ; and as a general rule, wherever the conditions of illumination from a number of incandescent lamps are uniform, it is very desirable to use a main switch to throw them in or out, although the varying conditions of load or current on the dynamo are such that it is not recommended that over fifty lights should be so connected with any one switch unless the conditions of the case are thoroughly understood and agreed upon. All switches used in the conductors of electric lighting installations, apart from those at the lamps, should be double pole, and should be mounted on incombustible bases with an indicator showing whether the switch is open or shut.

Every electric lighting plant should be provided with instruments of precision for measuring the out-put of the dynamo.

These instruments should be placed on the switchboard in a position where they will not be affected by magnetism from the dynamo.

The conditions of the operation of electric plants generally do not admit of the use of ordinary methods of measuring the resistance of the insulation between the earth and the system, and the magneto is used as a feasible method of indicating to some extent the presence of any ground of low resistance. Although this instrument has been severely criticised, yet it fills a useful purpose within the proper limits of its service. It is portable, can be used by any one, and the indications can be relied upon within the limits of the instrument. It is far more delicate than the galvanometer of 10 or 20 ohms resistance used in connection with two or three cells of a battery.

There is a tendency towards the increased use of currents of higher electro-motive force, wherever it is feasible to reach an economy of copper wire by such methods.

Because there is much that is strange, wonderful, and unprecedented in these applications of electricity, there has been a tendency on the part of the general public to expect too much from them, both by way of advantage and of mishap. In case of fire, the press frequently ascribe the results to electrical wires purely on presumption without any evidence to establish the fact. Furthermore, in many instances such allegations are made when the known facts or weight of presumptive evidence indicates a contrary cause. It has been fully established by the experience of the past twelve years that a well installed electric lighting plant is the safest method of illumination.

THE INJECTOR.

BY PROF. R. C. CARPENTER.

The injector is an instrument especially designed for feeding water to steam boilers, although it can be and often is used as a pump to raise water from one level to another. It has been used as an air compressor, and also for receiving the exhaust from a steam engine, taking the place in that case of both condenser and air pump.

It consists, in its most simple form, of a steam nozzle, the end of which extends somewhat into a second nozzle, called the combining or suction nozzle; this connects with, or rather terminates in, a third nozzle or tube, termed the "forcer." At the end of the *combining tube*, and before entering the forcer, is an opening connecting the interior of the nozzle at this point with the surrounding area. This area is connected with the outside air by a check valve, opening outward in the automatic injectors, and by a valve termed the overflow valve in the non-automatic injector. The injector nozzles are tubes, with ends rounded to conform to the form of the vena-contracta as nearly as possible, and thus receive and deliver the fluids with the least possible loss by friction and eddies.

Double injectors are those in which the delivery from one injector is made the supply of a second. Familiar examples of this kind of injector are seen in the Hancock inspirator and the Park and World injectors. The Hancock inspirator is non-automatic, and the operation of starting involves the opening and closing of several valves, quite confusing to the beginner.

The Park injector is automatic, and handled by a single valve. In the double injector, the one first receiving the water is termed the "lifter," the second one the "forcer." In the Hancock inspirator these are each complete injectors; the lifter must be first started and the by-pass valve on the side and the overflow valve opened, by means of which the lifter will discharge its water through the overflow. As soon as water appears at the overflow that valve must be closed, also the by-pass valve; then open at once the throttle to the forcer injector, and the stream of water, which had been heretofore wasted in the overflow, will be delivered under pressure to the second injector, where it will be again acted on by steam and delivered to the boiler at a still higher pressure. Double injectors will handle feed water at a somewhat higher temperature than single ones with fixed nozzles. The accompanying cuts of the Metropolitan and Schaffer & Budenberg injectors serve to show the methods of action.

The steam enters from above, the flow being regulated by the handle K. The steam passes through the tube S and expands in the tube V, where it meets the water coming from the suction pipe. The condensation takes place in the tubes V and C, and a jet of water is delivered through the forcer tube D to the boiler. Connection passages are made to the chamber surrounding the tubes C, D, and to the end of tube V. If the pressure in this surrounding chamber becomes greater than that of the atmosphere, the check valve P is lifted and the contents are discharged through the overflow.

So long as the pressure in this chamber is atmospheric, the check valve P remains closed, and all the contents must be discharged through the tube D. It will be noticed that these tubes decrease in size; thus in the Metropolitan injector, as tested by Burwell and Arnold in 1891, with ¾-inch suction and discharge pipe, we find the least diameter of steam tube S to be 0.217 inches and the least diameter of water tube D to be 0.151 inches.

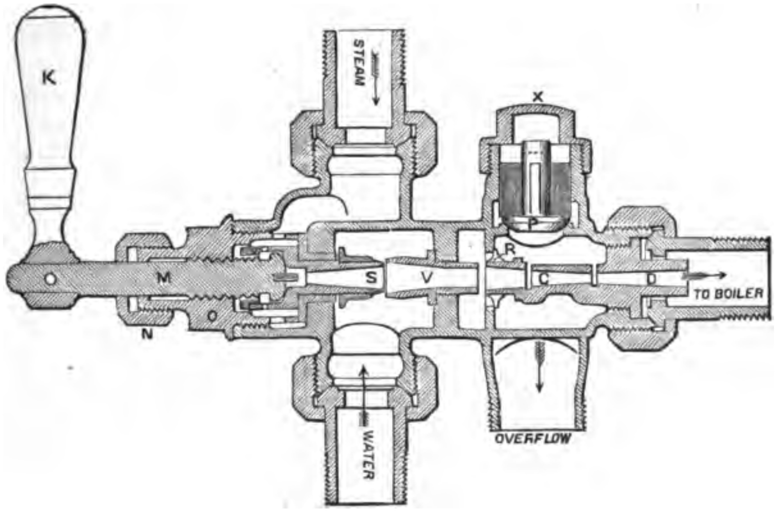

Fig. 1.

S, Steam jet; V, Suction jet; C-D, Combining and delivery tube; R, Ring or auxiliary check; P, Overflow valve; O, Steam plug; M, Steam valve and stem; N, Packing nut; K, Steam valve handle; X, Overflow cap.

The action of the injector is as follows: Steam being turned on, it rushes with great velocity through the steam nozzle into and through the combining tube. This action induces a flow of air from the suction pipe, which is connected to the combining tube, with the result that a more or less perfect vacuum is formed, thus inducing a flow of water. After the water commences to flow to the injector it receives an impact from the jet of steam; it absorbs heat from the steam and finally condenses it, and thereafter moves on into the forcer tube simply as a stream of water, at a low velocity compared with that of the steam. At the beginning of the forcer tube it is subjected only to atmospheric pressure, but from this point the pressure increases and the water moves forward at diminished velocity.

The motive force of the injector is found in the heat received from the steam. The steam is condensed, and surrenders its lat-

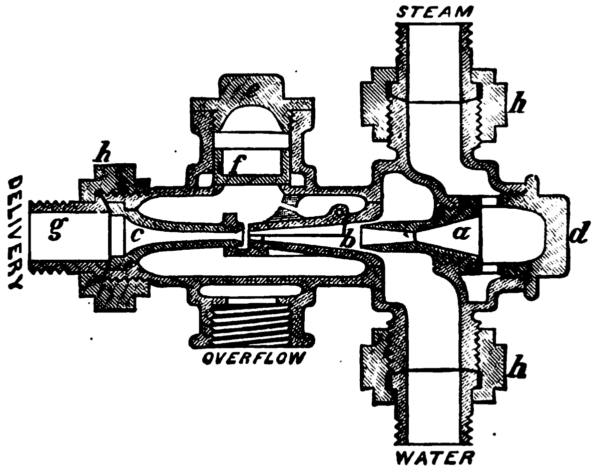

Fig. 2.

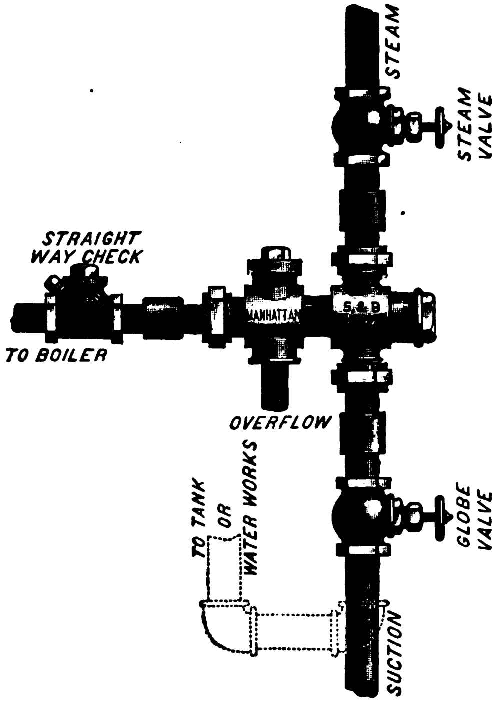

Fig. 3.

ent heat and some of its sensible heat. The energy so given up by each pound of steam amounts to about 900 thermal units, (B. T. U.) each of which is equivalent to a mechanical force of 778 foot pounds. This would be sufficient to raise a great many pounds of water against a very great pressure could it be so applied, but a large portion of it is used simply to heat the water raised by the injector.

As a thermodynamical machine, the injector is nearly perfect, since all the heat received by it is returned to the boiler, except such a very small part as may be lost by radiation ; consequently its thermal efficiency should be in every case nearly 100 per cent. On the other hand, because of the fact that its heat energy is principally used in warming up the cold water as it enters the injector, its mechanical efficiency, or work done in lifting water, compared with the heat expended, is very low.

THERMODYNAMICAL THEORY.

The thermal theory of the injector is very simple. The energy received from the steam in B. T. U. is, per hour the weight of steam (w), multiplied by the amount of heat which it loses (H — t), plus the heat given up by water brought in with the steam (T — t)(w′— w), plus the steam used in the mechanical work (F) of lifting a certain number of pounds of water against a given pressure and delivered at a given velocity. Multiplying by 778 gives the result in foot pounds.

The mechanical work consists of W pounds of water lifted h feet after it leaves the injector by pressure, and S feet before it reaches the injector by suction. The steam also lifts its own weight w′ against the head h. Hence the mechanical work in foot pounds becomes

$$F = (h + S)\,W + w'h, \quad (1)$$

if delivered without sensible velocity. If the feed water is received at a temperature t and discharged at a temperature t′, it evidently takes up $W\,(t - t') = K$ heat units, which is equivalent to

$$778\,W\,(t - t') \text{ foot pounds} = K. \quad (2)$$

If the water is discharged from the injector with a sensible velocity, as may sometimes be the case, let this velocity be v″, its energy would be the weight,

$$(W + w')\,v^2 \div g = L, \quad (3)$$

which should be added *to* the value of F as a part of the mechanical work. If we term the energy given up by the steam R, we have, as already explained, in foot pounds:

$$R = 778\,[w(H - t) + (T - t)(w' - w)] + F + L, \quad (4)$$

and the thermal efficiency,

$$E = (F + K + L) \div R, \quad (5)$$

which should in every case be nearly 100. These results may be expressed in B. T. U. by dividing by the factor 778. In this case, in B. T. U.,

$$R' = w(H - t) + (T - t)(w' - w) + [(F + L) \div 778].$$

MECHANICAL THEORY.

Besides the thermal efficiency, which is only concerned with the loss and transformation of heat, there should evidently be a mechanical theory, to explain its action, on different principles. Such a theory explains the action as the impact of a small body at high velocity, the steam in the steam tube, coming in contact with a large body moving in the opposite direction or at rest, the water in the suction pipe, and giving a resultant velocity common to the entire mass, the water in the discharge pipe.

The explanation is exactly similar to the striking of one ball against a larger one, resulting in the motion of the two balls as one with a common velocity. Thus if w' is the weight of the steam, and such water as it may contain, and v its velocity, its momentum is $w'v \div g = m$; if W is the weight of water lifted, and if its original velocity deduced from the suction head be negative and equal to V', its momentum is $W V' \div g = M'$; if V is the velocity of discharge, the common momentum is

$$M = (W + w')\,V \div g.$$

By the principles of impact,

$$\frac{w'v}{g} - \frac{W V'}{g} = \frac{(W + w')\,V}{g} \quad (6)$$

but because of loss of force by eddies and friction, $w'v$ will be greater than the second member of the equation.

Let e equal the ratio, then will

$$e = [(W + w')\,V + W V'] \div w'v, \quad (7)$$

which may be termed the efficiency of impact.

VELOCITY OF DISCHARGED WATER.

In order to find these various quantities we must know, or determined by observation, the weight of steam, the weight of water raised, the velocity of steam as it strikes the water, and the velocity of water in the suction pipe and in the discharge pipe. Knowing the weight of water raised at a measured temperature, its volume in cubic feet can be computed. The volume discharged per second, divided by the area in square feet of the least orifice through which it passes, will give its velocity in feet per second of time.

This may be reduced to a more convenient form, in which the area is expressed in square inches and the discharge in cubic feet per hour; thus, let c be the cubic feet of water discharged per second, C the cubic feet discharged per hour, a the least area of the nozzle in square feet, and A the area in square inches. The velocity in feet per second:

$$V = \frac{c}{a} = \frac{C}{3600} \times \frac{144}{A} = \frac{C}{25\,A} \qquad (6\text{ A})$$

VELOCITY OF WATER SUPPLIED.

The velocity in the suction can be found by ascertaining the equivalent head H′, and finding the velocity V′ as by free fall, in which case $V' = \sqrt{2\,g\,H'}$. The equivalent head H′ is greater as the supply or suction head S is less. Let p be the absolute pressure per square inch in the combining chamber, b the pressure per square inch of the water supply, and w″ the weight of a cubic foot of water; then

$$V'^2 \div 2\,g = H' = 144\,(p - b) \div w'' - S. \quad (8)$$

It is, however, found more conveniently, by considering a body of water with a head S, acting to accelerate or retard the whole mass of water in the injector. If water is delivered to the injector under a head, it would accelerate and be positive; if obtained by suction, it would retard the whole mass and be negative.

If we denote the number of pounds of water raised by one pound of steam, by Y, and the weight of steam by w, the total weight passing through the injector will be (Y + 1) w pounds.

Let a be the smallest section of the water-jet, and w″ be the weight of a unit of water, then the pressure or force exerted by S feet of water will be S a w″. This force acts upon a mass of water moving with a velocity V through the orifice a, with a density w″, so that its mass would equal V a w″ ÷ g. The velocity imparted would be

$$S a w'' \div \frac{V a w''}{g} = \frac{S g}{V} \quad (9)$$

The momentum imparted to (1 + Y) pounds of water would be

$$\frac{(1 + Y)}{g}\frac{S g}{V} = (1 + Y)\frac{S}{V} \quad (10)$$

This may be substituted for W V′ ÷ g of equation (6), giving the form used later in the examples.

VELOCITY OF THE STEAM.

The velocity v of the steam cannot be obtained by dividing the number of cubic feet of steam delivered by the least area of the orifice, because the exact pressure and quality of the steam at the instant of passing this orifice is unknown. Even if the pressure could be measured, the quality or per cent. of water would still be undetermined. As the volume diminishes rapidly with condensation, this is an important quantity.

In the case of the injector, the steam passes through a nozzle of varying cross-section, and there is little doubt but that as the area diminishes there is a certain loss of pressure, and corresponding increase of velocity, accompanied with a corresponding change in quality. In the absence of direct experiment it will be necessary to determine this velocity from the thermodynamical equations of flow. As in this case there is no loss or gain of heat except by radiation, which may be neglected, the flow must be adiabatic, or nearly so. In this case the work done must equal the loss of heat; thus, if x_1 is the quality of entering steam at an absolute pressure p_1 per square inch, L_1 its latent heat, x_2 the quality of steam in the nozzle, p_2 its pressure, and L_2 its latent heat; if S_1 and S_2 represent the sensible heat for the corresponding pressures, we have as the heat in one pound of steam before entering, $x_1 L_1 + S_1$, and after passing the nozzle, $x_2 L_2 + S_2$, the heat added by the work of changing pressure would be the product of the volume of one pound of water by 144, $(p_1 - p_2)$ reduced to thermal units.

The mechanical work of one pound of steam is $v^2 \div 2 g$, which, reduced to thermal units, is equal to the loss of heat. For if the expansion is adiabatic, any heat lost must appear in work. Hence we have, reduced to B. T. U.:

$$\frac{v^2}{2(778g)} = x_1 L_1 - x_2 L_2 + S_1 - S_2 + .016\frac{(p_1 - p_2)(144)}{778} \quad (11)$$

The last term when reduced becomes .003 $(p_1—p_2)$, if T_1 and T_2 represent respectively the absolute temperatures corresponding to the pressures P_1 and p_2, and if θ represent the entropy of the liquid, that is the number of heat units required to change from one adiabatic at zero pressure to another at the given pressure. Therefore from equality of heat

$$\frac{x_1 L_1}{T_1} + \theta_1 = \frac{x_2 L_2}{T_2} + \theta_2{}^{*} \quad (12)$$

The entropy is tabulated in Peabody's steam tables, which substituted in the above gives the necessary data to solve for X_2. To afford means of making this calculation the following quantities are taken from Peabody's tables :

TABLE OF ENTROPY OF THE LIQUID.

Absolute Steam Pressure p	Entropy of the Liquid θ	Absolute Steam Pressure p	Entropy of the Liquid θ
1	0.1329	65	0.4337
10	0 2842	70	0.4402
15	0.3143	75	0.4464
20	0.3363	80	0.4522
25	0.3539	85	0.4579
30	0.3685	90	0.4633
35	0.3811	95	0.4686
40	0.3921	100	0.4733
45	0.4020	105	0.4780
50	0.4109	110	0.4826
55	0.4191	115	0.4869
60	0.4267	120	0.4911

The following example will illustrate this method : What is the velocity of flow of steam through a nozzle in which the entering pressure is 80 pounds absolute, quality 98 per cent., and the discharge pressure 20 pounds absolute? In this case we have the following values, taking the absolute temperature as 461.1° higher than the temperature of the steam in degrees F.

$p_1 = 80$, $S_1 = 281.9$, $L_1 = 895.1$, $\theta_1 = .4522$, $x_1 = .98$, $T_1 = 773$.
$p_2 = 20$, $S_2 = 176.6$, $L_2 = 954.8$, $\theta_2 = .3363$, $T_2 = 690$.

From equation (12) :

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* Thurston's Steam Engine, p. 415. Peabody's Thermodynamics, p. 139.

$(.98)(895.1) \div 773 + .4522 = x_2(954.8 \div 690) + .3363$. Hence $x_2 = 90.4$.

Substitute this in equation (11), omitting the last term, which is very small, we have,

$$v^2 \div 1456\,g = 877.2 - 855.5 + 281.9 - 196.6 = 107$$
$$v^2 = 107 + 1456 + 322$$
$$v = 2347 \text{ ft. per sec.}$$

By substituting the value of x_2 of equation (12) in equation (11) and reducing, representing the mechanical equivalent, 778 by J.

$$\frac{v^2}{2\,J\,g} = \frac{x_1 L_1}{T_2}(T_1 - T_2) + T_2(\theta_1 - \theta_2) + (S_1 - S_2) + .003\,(p_2 - p_2)$$

from which v may be solved directly. (13)

In case tables of the entropy are not at hand, we can substitute for $\theta_1 - \theta_2$ its value by definition :

$$\theta_1 - \theta_2 = \int_{T_1}^{T_1} \frac{c\,d\,t}{T} = c\,\text{Log}_e \frac{T_1}{T_2}^{*} \quad (15)$$

In case c the specific heat equals unity,

$$\frac{x_2 L_2}{T_2} = \frac{x_2 L_1}{T_1} \div \text{Log}\,\frac{T_1}{T_2}$$

Substitute this value of $\theta_1 - \theta_2$ of equation (15) in equation (13) and we have,

$$\frac{v^2}{2\,g\,J} = \frac{x_1 L_1}{T_1}(T_1 - T_2) - T_2\,\text{Log}_e \frac{T_1}{T_2} + S_1 - S_2 + .003\,(p_1 - p_2) \quad (16)$$

This form is not quite as accurate as the form in equation (13), since it is deduced on the supposition that c, the specific heat of the liquid, is constant.

To apply this formula to the same example as before :

$p_1 = 80$, $S_1 = 281.9$, $L_1 = 895.1$, $x_1 = .98$; $T_1 = 773$.
$p_2 = 20$, $S_2 = 196.6$, $L_2 = 954.8$, $T_2 = 690$.
$\text{Log}_e\,(T_1 \div T_2) = .1133$, $S_1 - S_2 = 84\ 7$, $p_1 - p_2 = 60$, $T_1 - T_2 = 83$.
$v^2 \div 2\,g\,J = 92.8 + 84.7 + 0.2 - 78.2 = 99.5$.
$v^2 = 778 + 64.4 + 99.5$.
$v = 2233$.

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* See Thurston's Steam Engine, p. 442.

It may also be calculated in terms of the pressure :

$$U = \frac{v^2}{2g} = \frac{\gamma P_1 C_1}{\gamma - 1}\left(1 - \left(\frac{P_2}{P_1}\right)\frac{\gamma - 1}{\gamma}\right) *$$

in which P_1 and P_2 are the pressures per square foot, C the volume of one pound in cubic feet, and γ the ratio of the specific heats. So that $(\gamma - 1) \div \gamma = 0.1189$ for dry steam and 0.1111 for ordinary steam. This can be reduced to

$$v = 23.2987 \sqrt{P_1 C_1 \left(1 - \left(\frac{P_2}{P_1}\right)^{.1111}\right)} \quad (17)$$

To apply to same example as before,

$p_1 = 80$, $P_1 = 80 \times 144 = 11520$, $c_1 = 5.245$.
$p_2 = 20$, $P_2 = 20 \times 144 = 2880$, $(P_2 \div P_1)^{.1111} = (\frac{1}{4})^{.1111} = .8572$.
$v = 2162$.

Formula (13) is the most accurate, and, it is seen, also gives the highest velocity. Formula No. 17 is used by Prof. Wood to compute the velocity of flow, but in its strict application it applies to permanent gases only.

PRESSURE IN THE STEAM NOZZLE.

This is a difficult quantity to measure, especially in the small tubes used in injectors. Mr. R. D. Napier concluded, from a large number of experiments, that the pressure would never be less than that which would produce the maximum flow, and in this opinion he was upheld by Professor Rankine. His experiments indicated that the pressure of maximum flow was 60 per cent. of the pressure in the reservoir. Some experiments made by Professor Peabody seem to indicate that the pressure of maximum flow for saturated steam is 50 per cent. of the steam pressure.† In view of these experiments, it seems proper to assume the absolute delivery pressure from the steam nozzle at 60 per cent. of that of the absolute steam pressure.

By the application of equation No. 13, the following velocities

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* Thurston's Steam Engine, p. 369. Wood's Thermodynamics, p. 283.

† Peabody's Thermodynamics, p. 140.

are obtained, the delivery pressure being assumed 60 per cent. of the steam pressure :

Steam Pressures.			Velocity of Discharge. Feet per sec.
On Injector.		On Orifice.	
Absolute.	Gauge.	Absolute.	
93.5	80	56.1	1420
83.06	70	49.8	1405
73.2	60	43.9	1392
61.1	50	37.8	1397
53.2	40	31.9	1389
43.2	30	25.95	1380
33.4	20	20.06	1372

[In our next issue we will discuss the limits of action of the injector, the methods of testing, and the results obtained in the test made in 1891 by Burwell and Arnold.]—Editor.

ELECTRICAL MEASUREMENTS.*

I.

STANDARD GALVANOMETERS.

In the measurement of the electric current we make use (1) of its thermal effect, (2) of its chemical effect, (3) of its magnetic effect. The galvanometer is an instrument based upon the magnetic action of the current. A standard galvanometer is one by means of which the current may be determined in absolute measure directly from the dimensions of the instrument and the strength of the magnetic field in which it is placed.

In figure 1, L is the cross section of a conductor carrying current at right angles to the plane of the paper. The current is flowing from us. The lines of force are concentric circles, the positive direction along these lines being "clock-wise."

A magnetic particle μ will tend to move along the line of force in which it lies.

Let the conductor L be a circular coil of one turn, the plane of the coil vertical and at right angles with the paper. Let μ lie in

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* Notes of lectures delivered to Seniors and Graduate Students by Professor E. L. Nichols.

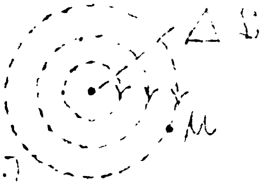

FIG. 1

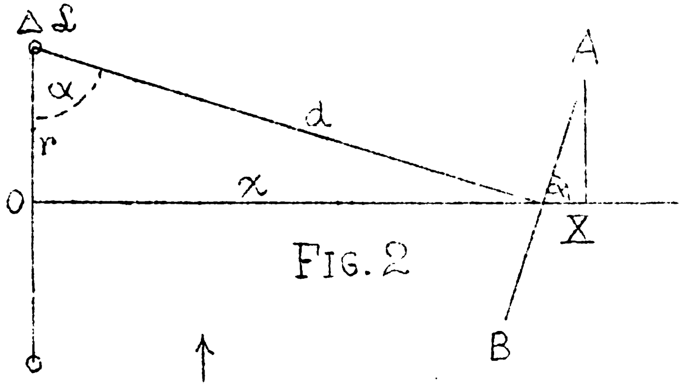

FIG. 2

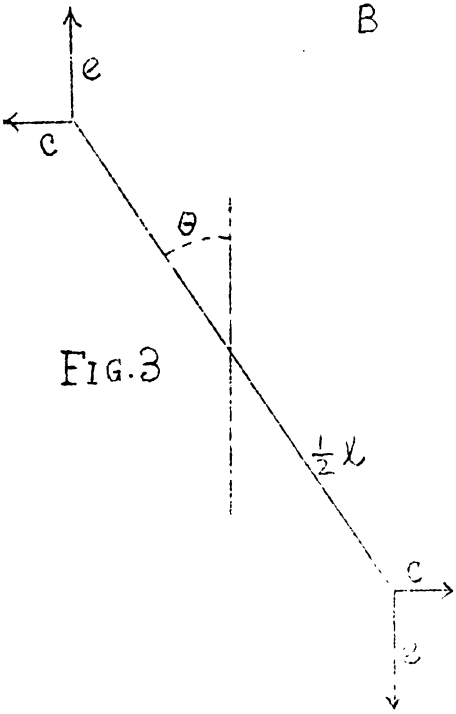

FIG. 3

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ASTOR, LENOX
TILDEN FOUNDATION

the axis of the coil (OX), (figure 2). The force ($F \Delta L$) due to an element of the conductor, (ΔL), tends to urge μ along the line A B tangential to the line of force. The value of this force is

$$F \Delta L = \frac{KCm\Delta L}{d^2} = \frac{KCm\Delta L}{r^2+x^2}$$

where C is the current, m the magnetic strength of the particle, K a constant depending upon the terms in which C, m and L are expressed.

The force exerted by the entire circle is

$$FL = \frac{KCm\,2\pi r}{r^2+x^2}$$

If the particle μ is free to move along x only, we have for the action of the current upon it

$$FC = FL \cos a = FL \frac{r}{d} = F_L \frac{r}{\sqrt{r^2+x^2}}$$

from which

$$FC = \frac{KCm\,2\pi r^2}{(r^2+x^2)^{\frac{3}{2}}}$$

We now pass to the consideration of a needle mounted with its center of suspension in the axis of the coil, the length of the needle being negligible, as compared with r. Under the combined action of the horizontal component of the earth's magnetism and of the current, the needle is deflected through an angle θ (figure 3). When the couples due to the earth and the coil are balanced, the needle comes to rest and we have

$$l \cos \theta\, F_c = l \sin \theta\, F_e$$
$$F_c = F_e \tan \theta,$$

where F_e is the earth's effect upon the needle.

Since the expression for the earth's force is $F_e = Hm$, we may write:

$$H \tan \theta = \frac{KC\,2\pi r^2}{(r^2+x^2)^{\frac{3}{2}}}$$

The constant k becomes unity when all quantities are expressed in absolute measure, and the value of the current is

$$= \frac{H \tan \theta}{\dfrac{2\pi\, r^2}{(r^2+x^2)^{\frac{3}{2}}}}$$

which is the equation of the tangent galvanometer with a single ring.

For an instrument with n turns of wire we have

$$C = \frac{H \tan \theta}{\frac{2\pi n r^2}{(r^2 + x^2)^{\frac{3}{2}}}}$$

When the needle is in the plane of the ring, the case most commonly met with, we have $x = 0$, $C = \frac{r}{2\pi n}$. $H \tan \theta$.

The equation just given fails to complete generality in four respects:

(1) The length of the needle is assumed to be negligible.
(2) The coil of the galvanometer is in the meridian.
(3) The coil of the galvanometer is vertical.
(4) The needle is in the axis of the coil.

In properly constructed tangent galvanometers the needle is, in fact, short enough to fully meet the conditions of our equation. The correction for long needles varies with the distance from the plane of the coil. It is a minimum when $x = \frac{1}{4} r$, for which position it can be shown that when

$l = \frac{1}{5} r$, the correction is .001.
$l = \frac{1}{6} r$, the correction is .0005.

In actual instruments l is almost always very much less than $\frac{1}{6} r$.

In case the second condition is not fulfilled and the plane of the coil makes an angle α with the magnetic meridian, the deflection to east and west, upon reversal of current, will not be of same size. Let the deflections be respectively θ_e and θ_w. We have

$$C\,G \cos(\theta_e + \alpha) = H \sin \theta_e,$$
$$C\,G \cos(\theta_w - \alpha) = H \sin \theta_w,$$

from which

$$C^2 = \frac{H^2}{G^2} \frac{(\tan \theta_e - \tan \theta_w)^2 + 4 \tan^2 \theta_e \tan^2 \theta_w}{(\tan \theta_w + \tan \theta_e)^2}$$

When α is very small, the usual case, we may write

$$C = \frac{H}{G} \tan \frac{\theta_e + \theta_w}{2}$$

In these and subsequent equations, G is the constant of the coils, [$G = \frac{2\pi n r^2}{(r^2 + x^2)^{\frac{3}{2}}}$, for the galvanometer with one coil of n turns], and $\frac{H}{G}$ is the constant of the galvanometer.

In the Helmholtz form of tangent galvanometer there are two coils, the distance between them being equal to r. The needle, situated between them at a distance $x = \frac{1}{2}r$ from the plane of each, is in a nearly uniform field, so that small displacements of the former from the axis introduce no appreciable error. The equation of the Helmholtz galvanometer is:

$$H \tan \theta = C\left(\frac{2\pi n_1 r_1^2}{(r_1^2+x_1^2)^{\frac{3}{2}}} + \frac{2\pi n_2 r_2^2}{(r^2+x^2)^{\frac{3}{2}}}\right)$$

or

$$C = \frac{H \tan \theta}{\left(\frac{2\pi n_1 r_1^2}{(r_1^2+x_1^2)^{\frac{3}{2}}} + \frac{2\pi n_2 r_2^2}{(r_2^2+x_2^2)^{\frac{3}{2}}}\right)}$$

In this formula, r_1 x_1 n_1 and r_2 x_2 n_2 are the values of r x and n for the two coils. If the coils are identical in size and number of turns, and if the needle is placed midway between them, the equation becomes,

$$C = \frac{H \tan \theta}{\frac{4\pi r^2 n}{(r^2+x^2)^{\frac{3}{2}}}}.$$

For the large tangent galvanometer in the Cornell magnetic observatory, which has four coils, the formula becomes,

$$C = \frac{H \tan \theta}{\left(\frac{2\pi n_1 r_1^2}{(r_1^2+x_1^2)^{\frac{3}{2}}} + \frac{2\pi n_2 r_2^2}{(r_2^2+x_2^2)^{\frac{3}{2}}} + \frac{2\pi n_3 r_3^2}{(r_3^2+x_3^2)^{\frac{3}{2}}} + \frac{2\pi n_4 r_4^2}{(r_4^2+x_4^2)^{\frac{3}{2}}}\right)}$$

The absolute sensitiveness of a galvanometer S_a, is defined by the equation $S_a = \frac{d\,\theta}{d\,c}$. By differentiation of the formula for the tangent galvanometer, $C = \frac{H}{G} \tan \theta$, we find $\frac{d\,\theta}{d\,C} = \frac{G}{H} \cos^2 \theta$, which is at a maximum when $\theta = 0°$.

The relative sensitiveness S_r is the quantity $C\,\frac{d\,\theta}{d\,c}$ therefore, $S_r = \frac{H}{G} \tan \theta . \frac{G}{H} \cos^2 \theta = \sin \theta . \cos \theta$ which reaches a maximum at 45°.

From this solution is derived the well-known rule in the construction of galvanometers, viz.: *The constant should be such that the average deflection will be, as nearly as possible, 45°.*

II.

MODIFICATIONS OF THE GALVANOMETER.

The sine galvanometer has a single coil which can be turned upon a vertical axis passing through the needle. In making a measurement the coil is rotated, following the needle until the latter comes to rest, in the plane of the coil, the angular displacement of which is then read from a graduated circle.

Under these conditions the equation is:

$$C = \frac{H}{G} \sin \theta.$$

The advantages are that the needle remains always strictly within the plane of the coil, and that the position of the latter can be read with very great accuracy by means of a vernier. The chief disadvantage is the time necessary to make a setting of the circle.

Calculation of the angle of maximum sensitiveness of the sine galvanometer by the method already indicated, gives

$$S_s = \frac{d\,\theta}{d\,C} = \frac{G}{H}\,\frac{1}{\cos\theta}$$

$$S_r = \frac{H}{G} \sin\theta.\ \frac{G}{H}\,\frac{1}{\cos\theta} = \tan\theta.$$

The maximum is approched in both cases as θ approaches 90°.

Galvanometers of Variable Constant.

It is frequently desirable to vary the constant through a wide range. This may be accomplished:

(1) By movement of the coil with reference to the needle.

(2) By variation of the strength of the magnetic field. [See galvanometers of high sensitiveness].

The coil is frequently moved in an east and west direction along its own axis, as in Thomson's graded ammeter, and in the earlier instruments devised by G. Wiedemann.

The coil may be arranged to revolve upon its horizontal diameter, the needle remaining at the center. The effect is to increase the constant from the normal value to infinity, the equation being

$$C = \frac{H.\tan\theta}{G.\cos\theta}$$

This construction is used in the Obach Galvanometer. Another convenient method of varying the constant is that made use of in the Moler "swinging arm" galvanometer, a form which recommends itself by its simplicity of construction.

Galvanometers of High Sensitiveness.

The development of galvanometers of high sensitiveness has been going on for more than half a century, and it is of great interest and importance to note the steps by which the present degree of delicacy has been reached. The various lines along which improvements have been made may be summarized as follows:

1. Reduction of the earth's action upon the needle.
2. Increase in delicacy of the needle suspension.
3. Reduction of the moment of inertia of the moving parts.
4. Improvement in the method of reading small deflections.
5. Increase in the length of wire acting upon the needle.
6. Reduction of the mean distance from the coil to the needle.

In all these directions the evolution of the galvanometer has been going on simultaneously, but it is convenient to consider each line of development by itself.

The first device for reducing the directive force of the earth's magnetic field was by means of the "astatic pair." Galvanometer needles were at that time simply steel sewing needles, which had been magnetized. Two such needles were connected rigidly, parallel, one above the other, their poles in opposition. The coils surrounded the lower needle only. The earth's action was differential, and could be reduced almost to zero by making the magnetic strength of the needles nearly equal. The current in the coil however acted in the same direction upon both.

A later device, which has entirely supplanted the astatic pair for most purposes, consists in the reduction of the earth's field by means of a bar magnet placed in the north and south direction, near the galvanometer. The result is to increase the time of vibration of the needle and to increase the sensitiveness of the galvanometer. The susceptibility of the needle to magnetic disturbance from without, increases at the same time however, and finally puts a limit to the application of this method. It should be noted that in the numerous cases in which sensitiveness may well be sacrificed to quickness of action and freedom from disturbance from without, the earth's field may be artificially strengthened by the proximity of a magnet properly placed.

The original galvanometer needle was a compass needle, upon a jewelled bearing. The substitution of a suspension fibre of unspun silk was a very early and important change. This material, after having been used for many years, to the exclusion of all other materials, has recently been supplanted by quartz fibre, which is much stronger. Quartz appears to be an ideal substance for the purpose, and its use has made it possible to increase the delicacy of the galvanometer to an extent previously unattainable.

The reduction of the moment of inertia of the moving parts in the galvanometer has been obtained by shortening the needle and reducing its mass, and by substituting for the pointer or index originally used, a light mirror. The highest development along this line is seen in the galvanometers of Sir William Thomson, in some of which the entire weight of the suspended parts is less than one grain.

The principal improvement in the method of reading small deflections, consisted in the introduction of a mirror attached to the needle, and the observation of the image on a distant scale in this mirror by a telescope. If the scale be situated 1.5 meters from the mirror, a deflection of 1 m.m. corresponds to an angle of less than 1′.

Advances in the process of making insulated wire have rendered it possible to bring an enormous number of turns in a galvanometer coil of small size. As many as 300,000 to 400,000 ohms have been placed in galvanometers of recent construction, the number of turns being correspondingly great.

The application of these various improvements has made the galvanometer an instrument of almost inconceivable delicacy. It is now found entirely practicable to make an instrument which, even though of quite moderate resistance, will give a readable deflection when traversed by a current of 10^{-10} ampères.

A COMMUNICATION.

There has been considerable talk lately, among the Sibley Seniors, concerning a graduate pin. Almost every one who has been approached has expressed himself in favor of it; but the question arises whether it should be a Sibley College pin, or a Cornell University pin with some distinguishing mark or emblem upon it to indicate the department or course. I should like to hear expressions of opinion from alumni and under-graduates, through THE CRANK.

—*Wants One.*

THE CRANK.

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THE SIBLEY PIN.

The Seniors in the Sibley College, as expressed in a communication published elsewhere in this issue, are desirous of having a Sibley pin. The sentiment of the students is divided as to what sort of a pin should be adopted, although everyone wants a pin which, to use a well-known aphorism shall be "neat but not gaudy." It is earnestly hoped that this idea will develop into a pleasant reality, as, in this age of pins and buttons, such a large and prosperous school as ours should certainly not be without a well and artistically made pin which every loyal man would gladly possess.

THE GRADUATE EDITOR.

In accordance with the notice published in the last number of THE CRANK, a meeting of the Board was held November 10th, at which after careful consideration of the material offered in competition, Mr. J. C. McMynn was elected to the position of Graduate Editor. After taking his A. B. degree at Williams College, Mr.

McMynn graduated here last year in Mechanical Engineering. He is at present pursuing advanced work in Electrical Engineering leading to the degree of M. M. E., and is therefore as the representative of the graduate and electrical engineering students, an exceedingly valuable addition to THE CRANK Board.

NOTES ON ELECTRICAL MEASUREMENTS.

Upon the solicitation of the students who are taking the course in Electrical Measurements, THE CRANK has commenced this month to publish full notes of the lectures. These notes are kindly furnished by Professor Nichols and represent no small amount of time and work. The publication of such material involves considerable extra expense and, as THE CRANK is an undergraduate publication and in no way subsidized, it is absolutely essential that the Sibley students who are taking this course of lectures shall furnish substantial support. Underclassmen, too, would do well to take THE CRANK now, as these notes will not be published again in its columns.

ROBERT FULTON, HIS LIFE AND ITS RESULTS.

BY ROBERT H. THURSTON, M.A., DOC ENG.

This small volume recently issued from the press of Dodd, Mead & Company, forms one in the series of books entitled "Makers of America."

The book is evidently intended to give the reader not only a biography of Fulton, but to show clearly the relation existing between his inventions and those of earlier and later inventors. The first two chapters are devoted to showing the condition of the steam engine and of steam navigation, preceding Fulton's time; the four intermediate chapters are devoted to the life of Fulton and to his various experiments; the last two chapters show the later development and possible future of steam navigation. The book is written in an entertaining style, is well illustrated, and intensely interesting. It contains the letters of Fulton to Jefferson, recording his experiments with submarine guns, published for the first time. The work clearly shows that the popular notion that Fulton was the inventor of the steamboat, is certainly erroneous, that Fulton merely carried into operation the plans and ideas of other people. He was a promoter of the enterprise and, by his persistency and address, he succeeded in making the steamboat a commercial success.

That Fulton was an inventor of great genius is shown by his later, and less successful productions. His submarine boat was, in the opinion of many eminent engineers, a perfect success, capable of rising or sinking at will, and of navigating below the surface of the water. This project was favored by our government but not so far completed, at the time of Fulton's death, to warrant adoption. Since his time this art can hardly be said to have improved.

It is clearly shown that Fulton is to be regarded to-day as a great engineer, projecting and carrying into execution great works, rather than as an inventor improving old forms of mechanism or producing new ones. The book will prove valuable to those desiring a history of steam navigation, and its probable extension in the future, as well as to those who are interested in the life and labors of Robert Fulton.

CRANK SHAFTS.

Notice.—Several copies of THE CRANK which have been returned, were so thoroughly soaked by exposure to the rain while lying on the mail boxes, that it was impossible to distinguish the names of those who returned them.

The foundations for the new triple expansion engine are almost completed.

The new graduate course in Marine Engineering promises to become very popular. Already eleven students are registered in the course.

Schæffer & Budenberg of New York, have recently presented to Sibley College an expensive hydraulic gauge reading to 10,000 pounds pressure.

The castings of the small duplex Holly pump, presented to Sibley College by W. R. Shapleigh, '91, have been finished and the pump erected in a manner creditable alike to the students and the instructors.

An old gentleman from Owego visited Sibley College a short time ago. He was a blind mechanic but had a wonderful faculty of comprehending the construction of the various models in the museum by passing his hand over them.

A sectional 4½"×2¾"×4" duplex pump, the gift of Henry R. Worthington, has been received. The pump is an excellent model of workmanship, and shows clearly the structure and perfect arrangement of the valves and details.

Shortly before Instructor Chesebrough's departure for California, the Senior Engineers gave him a well filled purse as a token of their esteem and respect for him. Encircled by a large number of students, Mr. Wiseman made the presentation speech, to which Mr. Chesebrough replied in a few words, expressive of his sincere regret at leaving Cornell and "the boys."

Among the members of the faculty of the College of Mechanics and Engineering, University of Wisconsin, there are the following Cornell graduates: Dugald C. Jackson, Professor of Electrical Engineering; Charles I. King, Professor of Mechanical Practice; Albert W. Smith, Professor of Machine Design; Charles B. Wing, Professor of Bridge and Hydraulic Engineering, and C. A. Van Velzer, Professor of Mathematics.

The directors of the Yale & Towne Manufacturing Co., through their president, Mr. Henry R. Towne, the non-resident Sibley College lecturer, have presented to the university, for use in the mechanical laboratory of Sibley College, the 60,000 pound testing machine which has been used in standardizing the machines built by them under the patents of Mr. A. H. Emery, and which have been considered such marvels of fine work.

PERSONALS.

'83.

Henry E. Longwell is manager for Westinghouse, Church, Kerr & Company, Chicago, Ill.

'88.

W. W. Norton is superintendent of a smelting and refining works at East Helena, Montana.

A. H. Eldridge is at the Sioux City Iron Works, designing some new engines, and sends a set of blue prints of his latest work, as a contribution to the collection of Sibley College.

'89.

A. C. Balch is superintendent of an electric lighting company in Seattle.

F. M. Whyte is in the office of the Superintendent of Motive Power on the B. & O. Railroad.

C. V. Kerr, P.G., is Professor of Engineering at the Arkansas Industrial University, Fayetteville, Ark.

E. A. Hitchcock is working with the Corliss Steam Engine Co., where he has now been for nearly a year.

Lee Parker has been in town for a few weeks. He is now with the Short Electric Co. at Cleveland, Ohio.

H. H. Morehouse has charge of the Alumbrado Electric plant at Quezaltenango, Gautemala, Central America.

W. W. Churchill is in the mechanical stoker department of Westinghouse, Church, Kerr & Co., at Pittsburgh, Pa.

F. G. Gasche has been with the C. B. & Q. Railroad Co., at Aurora, Ill., for the last fifteen months, of which he has spent eight months in the erecting and machine shops, and the rest of the time in the laboratory, which, next to the Pennsylvania Railroad laboratory at Altoona, is the most complete laboratory in the country.

'90.

W. Howell is with the Otis Elevator Co., Yonkers, N. Y.

W. B. Tobey is in Sanley's laboratory at Pittsfield, Mass.

E. C. Fisher is with the Murphy Furnace Co., at Chicago.

W. N. Smith is with the Thomson-Houston Co., at Chicago, Ill.

C. Humphrey is with the Edison General Electric Co., at Kansas City.

H. P. Broughton is with the Municipal Lighting Co., at St. Louis, Mo.

Chas. Roess has returned to the University and taken up his work with '93.

O. A. Stranahan is with Westinghouse, Church, Kerr & Co., at Chicago, Ill.

H. M. Marble is studying patent law in the office of his father at Washington, D. C.

W. R. Webster and G. C Hicks are with Westinghouse, Church, Kerr & Co., at New York.

E. H. Waldo, R.G., and J. W. Cowles are with the Thomson-Houston Electric Co., at Lynn, Mass.

W. S. Monroe is with Burnham & Root, architects, Chicago, Ill. His specialty is sanitary engineering.

S. Fortenbaugh, who is with the Short Electric Company, of Cleveland, Ohio, was visiting friends in town recently.

J. C. Ramage was in town at the commencement of the vacation, and was greatly pleased with the changes that had been made since his graduation. He brought some interesting contributions to our collections, among which were indicator diagrams taken from one of the large B. & O. engines at very high speeds, between Washington and Baltimore.

CURRENT EVENTS.

Football:—October 24, at Percy Field, Cornell 30, Lafayette 0; October 31, at Rochester, (2d eleven) Cornell 21, Rochester 10; November 7, at Percy Field, Cornell 24, Lehigh 0; November 10, at Percy Field, Underclass contest, '95–5, '94–4. The 'Varsity team plays Princeton at Princeton, on November 14; U. of M., at Detroit, on November 21; University Club, at Chicago, on November 26; U. of M., at Chicago, on November 28.

The Fall Games were held at Percy Field, Saturday, October 21. A large number entered, and the following Cornell records were made: 100 yards dash, 10¼ seconds; 120 yards hurdle, 18 seconds; running broad jump, 20 feet, 4½ inches.

Columbia, University of Pennsylvania, and Cornell have formed an Intercollegiate Rowing Association. The annual regatta will take place at some point on the Hudson River, probably at Newburgh.

Professor Chas. M. Tyler delivered his opening address as Professor of The History and Philosophy of Religion and Christian Ethics, at Barnes Hall, October 21.

An effort is being made to raise $1000 by subscriptions, to endow a Cornell Pew in the new American church at Berlin.

Senior class election occurred October 28. J. L. Elliot was elected President.

On Thursday, November 5th, the first Chamber Concert of a series of five, was given at Barnes Hall. The artists were Miss Aus der Ohe, pianist, and Emil Fischer, basso. Damrosch's Orchestra has been secured for the next concert, in December.

A delightful Military Hop was given at the Armory, Friday evening, November 6.

Just before going to press word is received that Princeton beat Cornell 6–0. Two half-hour halves were played, and Princeton scored during the last half minute, playing a very rough game throughout. The umpire was from Princeton.

Cassier's *Magazine* is this month added to the list of high grade engineering monthlies. The first number vies with the best literary magazines in its style and make-up, and contains a large number of illustrations, the frontispiece being a portrait of Dr. Thurston. A sketch of Dr. Thurston's life and work is given, with the views of the interior and exterior of his home on the Campus. The tendency of the *Magazine* will be to present articles of a popular nature in all branches of engineering, including a limited number of trade notices. The next issue will contain an illustrated article by Professor Carpenter on the Mechanical Laboratory and Laboratory Practice at Cornell.

THE CRANK

THE SIBLEY

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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

HEAT FROM ELECTRICITY.*

Different applications of electrical heating may, for the purposes of the present paper, be classified under these four heads: 1st, its use in the arts, as in welding and smelting; 2nd, its application to the heating of street cars; 3rd, the heating of isolated plants, and 4th, the heating of a more or less extended area from the central station.

While there is unquestionably a large field for work under the first of the above headings, lack of time will prevent more than a passing glance at its general features. To the remaining three lines, our attention will be chiefly directed; for although, with the exception of a very limited use of the electric heater on some street-car lines, nothing practical has been done in these directions, still the general interest in the subject, as shown in the Patent Office Reports, as well as the wonderful facility with which a current lends itself to this kind of use, seems to justify a systematic study of the subject from an economical standpoint. Accordingly in the following pages our aim shall be tó determine under what circumstances the current can be used with commercial success for heating purposes.

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*Selection from a thesis for the degree of M. E. by George Ray Chamberlain and Francis Cary Caldwell, A. B. 1891.

Taking up then, these four divisions of the subject in order, we shall first consider very briefly the use of electric heat energy in the solution of the problems that occupy the mechanical engineer. Here as elsewhere the wonderful adaptability of the current is conspicuously shown. If we would use a fire to accomplish our purpose we must place it in a chamber of just about such a size and shape; we must provide an outlet for the products of combustion, through which there would also escape twenty or more per cent. of our available heat, also a tall chimney or some mechanical arrangement must be provided to supply air. Further, if we wish to use the heat locally, for melting some body, such as iron or glass, for welding or for other purposes, the amount of heat lost will bear a very large proportion to that usefully employed. On the other hand if we take our heat from the electric current, it can be supplied in any shape into which a wire can be bent, there is no combustion and thus no heat would be lost, in local application, except what goes by radiation and conduction. Further, the intensity of the heat can be increased far beyond the limit of the heat of combustion, thus adapting it to uses where fuel is out of the question. The principal uses to which the current has been put, so far, are but two, namely, welding and aluminum smelting, both of which have been too thoroughly described by others to require treatment here. A few other applications of the current, of minor importance, deserve passing mention, as showing, again, the great possibilities for its use. Such are its use in electrical soldering irons, iron heaters, an application to the ignition of substances in the chemical laboratory, in surgery, etc. Attention may also be called to a fact that, if any substance could be found of which to make pots, at once sufficiently refractory to stand the heat necessary, and a sufficiently good conductor of electricity, the current could be used with great economy for the manufacture of glass and other similar purposes.

HEATING STREET CARS.

With this sketch of the first topic we must content ourselves, and now turn our attention to the subject of the heating of street cars. In this comparatively little has been done, and where the system has been adopted it has probably been more for reasons of convenience than economy. But as between the small and often overheated stove and resistance coils at a moderate temperature, strung beneath the seats and thus taking up no useful room and making no one uncomfortable, a comparison as to convenience is entirely out of the question. Economically considered the great recommendation of this system is that no addition to the generating plant is required, since its capacity must already be greatly in excess of its average use, and by proper arrangements the heaters should take up this excess when it is not otherwise employed, and it should be thrown out, when the demand for the motive power is great; thus for instance the first motion of a driver's switch in turning the current on to the motors should throw the heater out automatically, so that the whole current would be available for starting, after which the heaters would be thrown in again independently.

Thus the only factor to be considered in the estimation of economy is the cost of power. In the less frequent case of the use of water power, this would probably be nothing, since the power paid for would be the maximum used, or if the company had their own dam the result would be the same. This also would hold, though in a slightly lesser degree, where fuel is excessively cheap, as in the use of culm banks. But when we come to the use of steam under ordinary circumstances, we have to estimate the relative efficiencies and the prices of fuel in the boiler and the car stove; and the very low efficiency of the steam engine, works havoc with the results. For average conditions we may take the efficiency of the boiler as 75%, the engine at 5%, the dynamo at 80% and the line at 95%, thus we have for the final efficiency of the fuel in heating the cars only 2.7%. Taking an especially favorable case, we may take instead, for the various efficiencies, 80, 85, and 97%, and we have 5.3% for the total. On the other hand, the stove, however abominable from the standpoint of convenience is by far the most economical method of heating, and even in one so small as that used in the street car, an efficiency of at least 50% could probably be relied upon. Thus, even allowing that the fuel to be used in the boiler were considerably cheaper than that for the stove, competition, under normal conditions, between 5% and 50% efficiency would be quite out of the question. Again although the statement was made above, that no addition to the plant would be necessary, this might not be true with regard to the boiler, which would necessarily be larger than needed for the average load. There is, however, another factor which would doubtless cast its weight on the side of the electric heater, and which in some cases would probably go far toward equalizing the claims of the two systems, if it did not reverse them. This is the fact that a stove must take up the room of at least one and perhaps two passengers. So that if the line were short, or if the travel were transient, and the cars usually much crowded, a very perceptible diminution in the number of passengers that could be accommodated might result. In which case, the introduction of electric heating apparatus might easily save more than the whole cost of heating. It may be of interest in this connection to give the figures reported by Lieut. S. D. Greene of the Sprague Co. on a test of the Burton Heater. He gives $3,00 per day for thirty cars or ten cents per day per car. The street car as ordinarily equipped with four Burton Heaters, would consume three horse-power, according to the estimate of the company, when all running at normal capacity ; if allowing the horse power to cost $40.00 per year and that the heaters will run at but half their normal capacity when in use, and will be in use but half the year, the cost per day would be but seventeen cents. Deducting from this the value of fuel otherwise burnt in the car, it will be seen that but very few five-cent fares need be gained by the room otherwise occupied by a stove to pay for this cost.

COST OF WATER POWER.

An extensive table is given in the thesis, gleaned partly from private sources but chiefly from the census reports of 1880, which shows that supposing an actual efficiency of 80 per cent, the charge per H. P. per year varies from $5 up to $25, occasionally falling to $2.50 or $1.25 per H. P. when 1000 H. P. are taken. To this must be added interest and repairs on the plant, which in the case of 2000 H. P. would probably amount to 28 cents per H. P.

COST OF COAL in various portions of the country is equally variable, and for that reason in the two equations of cost given, the price per H. P. and the price per ton are made independent variables.

(*To be concluded.*)

MODERN ADVANCES IN CHEMISTRY.*

BY PROF. F. W. CLARKE.

In a few introductory words Dr. Thurston presented the speaker, who is a member of the U. S. Geological Survey, mentioning also the important relation which he sustained to the science of chemistry. Professor Clarke began by saying that he did not see why he had been invited to speak to students in mechanical engineering, and that he should be surprised if he said anything of especial interest to them. He received, however, the closest attention, and all were well pleased.

Professor Clarke said:—The conception of an idea, like the meaning of a word, changes with age; we speak of the elements, our forefathers spoke of the elements, the ancients spoke of the elements. The Aristotelian ideas of the latter, who called the elements earth, air, fire, and water, were not like those now entertained, but were definitions of attributes, descriptive terms serving to classify properties rather than to define substances. They spoke of the alchemical elements sulphur, mercury, etc., as salts. Robert Boyle, from whom many of our ideas of chemistry come, who is known as the "Father of Chemistry, and Brother of the Earl of Cork," did much toward the advancement of the science. Chemical elements, as we know them, are defined as those which can be separated from known compounds and defying further separation, may, under proper conditions, be recombined. We owe much to Le Boise, who introduced the balance as an instrument of precision; also to Sir Humphrey Davy, whose achievements are too well known to need mention.

The number of elements is at present an open question. Sixty-nine are known positively, while seventy-two are regarded as established. These differ very greatly in abundance, and I have carefully tabulated them with respect thereto; the more important ones being given in Table I:

TABLE I.

	A	B	C	D	E
Oxygen	46.96	47.28	46.85	46.94	46.65
Silicon	28.88	28.88	28.23	27.91	27.34
Aluminium	8.31	9.32	8.51	7.75	7.96
Iron	4.11	4.09	3.96	5.77	5.47
Calcium	3.22	3.27	4.39	3.71	3.78
Magnesium	1.44	1.85	2.58	2.07	2.69
Potassium	2.94	2.24	1.49	2.54	2.41
Sodium	2.43	2.74	2.46	2.21	2.37
Hydrogen	.19	.18	.12	.23	.22

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* Abstract of a lecture delivered before the students of Sibley College, Cornell University, Nov. 13, 1891.

TABLE II.

	Rock 93 per cent.	Ocean 7 per cent.	Total.
O	46.65	85.79	49.98
Si	27.34		25.30
Al	7.96		7.26
Fe	5.47		5.08
Ca	3.78	.05	3.51
Mg	2.69	.14	2.50
Na	2.41	1.14	2.28
K	2.37	.04	2.23
H	.22	10.67	.94
Tn	.33	2.08	.30
C	.22		.21
Cl	.01		.15
P	.10		.09
Mn	.08		.07
S	.03	.09	.04
N			.02

The use of the spectroscope upon the nebulae has added no elements to those found upon the earth. I have made careful estimates, taking rock for analysis from the primitive or volcanic formations, which form by far the greater portion of the earth's crust. The superficial masses being merely detrital material, whose substance has undergone more or less change. The estimate is taken on a shell ten miles in thickness, it being thought that the earth's mass is nearly uniform to that depth, and also because the mass of this shell can be accurately computed. The apparent difficulties in determining the composition of this shell far exceed the real ones. While here, at Ithaca, we have great masses of limestone, and in other sections, masses of other rock material, yet the per cent. is so small as to vanish in the remote decimals when compared with the earth's mass. In the table, those values in column A are the averages of 22 analyses of rock from the 44th parallel; in column B, of 64 from the Yellowstone Park; C, of 54 volcanic rocks from Northern California; D, of 75 European volcanic rocks, and E is the general mean of 880 miscellaneous volcanic and crystalline rocks.

It can easily be shown that these results are not over 1 per cent. in error. Of the extraneous matter, iron, copper, tin, salt, lime, gypsum, etc., the per cent is so small that the fourth decimal place is not affected; the same being the case with the fresh water of our Great Lakes. The ocean water data are taken from the report of the Challenger expedition. The percentage of carbon in the earth's crust appears to be very small, but the data are reliable. It will be noticed that titanium is in greater per cent. than carbon, for it is found largely distributed in all rocks, and largely in clays. It will also be noticed that the elements upon which life depends, carbon and nitrogen, are very rare. The first nine elements in the list form 98% of the entire earth's mass, all heavy elements above 7.8 sp. gr. being exceedingly rare. Some theories would support the idea that the heavier elements settled at the center as the earth cooled, and lead to the conclusion that the center of the earth is a vast mine of gold, platinum, etc. This is fallacious, because the mean density of the earth's crust is 2.56 and of the earth's total is 5.57, the ocean being 2.6.

Obviously the earth should be much heavier at the center on account of the internal density, due to external pressure, and recent investigations go to show that the lighter elements are predominant in the earth's mass. The classification of the elements was first made according to the periodic law of atomic weights by Mendelejeff, the Russian chemist, showing that the properties are periodic functions of the atomic weights. This discovery shows that the elements are related to one another, and leads to the theory that they are all one in origin. We call a substance a chemical element, because we cannot decompose it, thereby only defining our own limitation. The nebulæ, when carefully examined, were many of them found to be star clusters, thus partially overthrowing the nebular hypothesis; but further use of the spectroscope showed many nebulæ to be bodies of gas of one or more elements, others not being discovered. This appears to be strong evidence in favor of the theory that the lighter elements, hydrogen, nitrogen, etc., were first evolved from the original gas.

Again, by referring to this table of atomic weights, familiar to all students of chemistry, we will notice that there are certain failures in the law of periodicity, and it will be of interest to know that when the table was compiled in 1869, there were three other vacancies which have since been filled by gallium, scandium, and germanium. Strange to say, however, the author of this table does not accept the theory of unity which they go so far toward proving.

We are familiar with the phenomena of allotropism and isomerism. We know in many cases two different substances are composed of the same proportional parts of the chemical elements. Also that of a series of chemical compounds, the first members are simple, but as higher points are reached great complexity is noted. We can also compare groups, finding that they have similar modifications. The final question then arises: Can we transmute one element into another? The older alchemists were easily led to believe that this was the case when they could change wood to charcoal and sulphur to sulphuric acid, and vainly endeavored to discover a way of making gold. While we can see through their limitations, yet with our grasp of the science of chemistry, is it not possible that we shall yet be able to change one element into another?

Professor Crook, in England, thinks it will be accomplished sometime, and will probably be the splitting up of one element into simpler ones. As a speculation, farther research in this direction may be desirable, but as a pursuit, it is not. In our study, the pendulum swings to extremes, and we may possibly reverse the process of evolution. The problem is an almost hopeless one, yet it must be faced,—is all matter evolved from one original simple element?

THE INJECTOR.—II.

BY PROF. R. C. CARPENTER.

LIMIT OF ACTION OF THE INJECTOR.

The limit of action can best be perceived by a discussion of an equation not given in the preceding article. An equation, which we may term fundamental, can be obtained from the fact that the work done, reduced to British Thermal Units, (B. T. U.), must in each case be equal to the transformation of heat. Denote by h the head of delivery in feet, S the height of suction in feet, V the velocity of delivery, t' the temperature of the feed water, t the temperature of the discharge water, W the weight of water, w the weight of steam, r the radiation loss in B. T. U., x the quality of steam, T its temperature, R the number of heat units in one pound of steam above zero, L the latent heat in B. T. U. In such case $R = xL + T$. The mechanical work done is $(W + w)h + WS$. The heat used in work is $w(R - t) - W(t - t') - r$, since this is the difference between that given up by the steam, and that received by the water corrected for the loss by radiation. Equating these values, using J to represent the mechanical equivalent of one thermal unit, we have, neglecting radiation loss,

$$(W + w)h + WS = J[w(R - t) - W(t - t')].$$

Denote the ratio W ÷ w by Y, then by solving, we shall have

$$Y = \frac{J(R - t) - h}{h + S + J(t - t')}$$

There is another condition that must be satisfied in all the equations of the injector, and that is that the amount of water must in all cases be sufficient to condense the steam, at atmospheric pressure. The injector will not work unless all the steam is condensed, and this operation must take place at the boiling temperature of water, for the pressure, acting on the combining tube, which is usually atmospheric, denote this temperature by t''. Then

$$W(t'' - t') = W(R - t''),$$

is the equation of condition of condensation, no work being done; from this

$$Y = \frac{W}{w} = \frac{R - t''}{t'' - t'} \quad (20)$$

for its least or limitiug value.

The injector will cease to work, if the value of Y or the weight of water to that of steam falls essentially below the above limit, and this condition, regardless of any other consideration, determines the least value of Y.

The limit of suction head (S) is to be obtained from equation (8) in which V' equal the velocity of flow from the suction pipe, H the equivalent head inducing this flow, S the suction head, which is positive if the water is supplied under pressure, p the pressure in pounds per square inch on the surface of the supply tank, b the absolute pressure on the combining tube, w'' the weight of a cubic foot of water at the temperature of the supply.

$$H = \frac{V'^2}{2g} = \frac{144}{w''}(p - b) - S. \quad (8.)$$

If a perfect vacuum in the suction b = 0, and if the temperature of the water is so low as to give off no vapor with sensible pressure, p equals the pressure due to the barometer reading; but if the temperature of the supply water is higher, the pressure of the vapor must be deducted from that of the atmosphere.

The following table gives the pressure of this vapor for feed water of different temperatures, also the amount of feed water required to condense one pound of steam at 100 pounds absolute pressure, and the greatest possible suction head, for atmospheric pressure of 14.7 pounds.

TABLE III.

Temp. of Feed wat'r Degs. F.	Pressure of Vapor, Pounds.	Limit of suction head against perfect vacuum.	Steam Pressure.	100 lbs. Absolute.
			Delivery 212°. No. of lbs. of water to one of steam. Y.	Delivery 180°. No. of lbs. of water to one of steam. Y.
70	0.36	32.96	7.04	8.81
80	0.50	32.6	7.57	9.61
90	0.69	32.2	8.19	10.76
100	0.94	31.4	8.92	12.11
110	1.26	30.9	9.80	13.84
120	1.68	29.7	10.87	16.15
130	2.22	27.3	12.20	19.32
140	2.87	25.9	13.89	24.22
150	3.70	24.8	16.13	32.3
160	4.72	22.5	19.23	48.45
170	5.98	19.6	23.81	96.90
180	7.50	16.9	31.25	. .
190	9.33	9.9	45.46	. .
200	11.52	9.3	83.33	. .
210	14.12	1.1	500.9	. .

The foregoing table is well worthy a careful study. It shows the increase in the water needed for simple condensation purposes only, where the delivery is 212°, to vary from 7.04 pounds to over 500 pounds for each pound of steam, as the temperature of the feed water increases from 70° to 210° F. It will be interesting also, to note the effect of the rise of temperature on the suction head, as given in the second and third columns. The effect of increase of temperature of the supply too, is to decrease the possible suction head and to increase the amount of water required for condensation. It may also be noted that because of the transformation of some heat, the amount of water needed for condensation purposes will be somewhat less than the above amount, when the injector is at work. This amount would be required, however, in each case on starting the injector, since at that time the water is discharged through the overflow and very little work is done.

Water delivered for one pound of steam.—This quantity is expressed by the symbol (Y), and the value is given in equation 19, conditioned by a minimum value as given in equation 20, for starting the injector. Since R, the heat in one pound of steam is a function of the pressure, the value of Y will increase with higher steam pressure. It should also increase with the temperature of the supply water t', since that would have the effect of reducing one of the terms in the denominator, the increase however of this quantity, requires such a rapid increase in the value of Y, in order that the steam may be condensed, that the injector is soon likely to reach its limit of maximum work and fail. This value will diminish with increase of head, either of supply or of the suction, or of that of the delivery temperature.

The injector in its usual condition, has a fixed suction head, and receives steam at a given boiler pressure, so that the only conditions that vary are the temperature of the feed water, the corresponding temperature of discharge and the weight of water per pound of steam. To find the maximum amount of water discharged for one pound of steam, we will combine equations (6) and (9) of the preceding article, from which we deduce

$$Y = \frac{v}{V - \frac{Sg}{V}} - 1. \quad (21.)$$

For a maximum value the velocity of discharge equals the $\sqrt{2gh}$ in which h is the delivery pressure expressed in feet.

Making this substitution

$$Y = \frac{v\sqrt{2gh}}{g(2h-S)} - 1. \quad (22.)$$

When $S = 0$ this becomes

$$Y = \frac{v}{\sqrt{2gh}} - 1. \quad (22A.)$$

From inspection of this equation it is seen that the water delivered for one pound of steam, depends on the velocity of steam in the combining tube directly, and on the square root of the delivery head inversely.

In the preceding article the value of v was calculated for different pressures inducing flow and in the throat of the nozzle, and it was shown in the calculations that the velocity remained about the same, for a given fractional reduction of pressure from the initial, regardless of the absolute amount. Thus the velocity of outflow, if the pressure is reduced to 25 per cent. of the initial pressure, by expansion and doing no work, would be about 2350 feet per second, regardless of the initial steam pressure, although very slightly increasing with higher pressure; if the pressure be reduced to 60 per cent. the velocity would be almost exactly 1400 feet per second, differing very little for change of pressure, if the pressure be reduced to 50 per cent. of the initial, the velocity of flow would be 1625 feet per second.

Using 1400 feet per second as the most probable value of V, we obtain the following results as the maximum value of the ratio (Y) of water to steam, when delivery pressure is equal to that in the boiler.

TABLE IV.

Absolute Pressure. Pounds per Sq. in.	Maximum Ratio. Water to Steam.	Absolute Pressure. Pounds per Sq. in.	Maximum Ratio. Water to Steam.
100	11.5	50	16.17
95	11.8	45	17.0
90	12.1	40	17.87
85	12.6	35	19.5
80	12.9	30	20.94
75	13.3	25	23.8
70	13.7	20	25.60
65	14.3	.	. . .
60	14.75	.	. . .
55	15.5	.	. . .

It is interesting to compare this with the maximum values obtained by experiment in the investigation by Burwell and Arnold in 1891. In this case three injectors were tried and the following was the maximum ratio of water to steam; in each case the injector was delivering water against a head equivalent to the boiler pressure.

Maximum value of Y by experiment.

TABLE V.

Absolute Pressure. Pounds per Sq. in.	Maximum Ratio of Water to Steam.		
	Hancock Inspirator.	Park Injector.	Metropol. Injector.
95	11.4	. . .	. . .
95	. . .	11.2	. . .
92	11.5	. . .	. . .
85	11.8	. . .	. . .
83	12.6	11.7	11.9
75	. . .	. . .	12.0
73	. . .	12,6	. . .
72	14.5	. . .	. . .
65	. . .	. . .	13.3
63	. . .	14.0	. . .
60	15.5	. . .	. . .
55	15.8	15.0	. . .
43	19.0	17.0	. . .
33	21.5	19.9	. . .

The agreement between the theoretical limit and the experimental one is quite striking, and indicates that the equation (22) can be used with confidence to determine the maximum ratio of water that can be raised for one pound of steam. This close agreement of experimental with theoretical results may indicate two things: first, that there is very little frictional resistance in the injector; second, that the velocity of flow is greater than that assumed, and that the frictional losses are much greater.

If we assume that the first hypothesis is true, it will be seen that the limit of perfection in the injector has been nearly reached and that it is hopeless to expect radical improvements. The great defect of the injector is its inability to handle water of high temperature, and, as will be shown later, it is not as economical for feeding boilers as a feed pump, when the exhaust steam can be utilized for heating the feed water. This defect comes from the fact that the ratio of water to steam, when the feed water is of high temperature, is not sufficient to condense the steam, and consequently the injector fails. Table III gives the ratio of water to one pound of steam necessary for condensation with different temperatures of the feed water. Table IV gives the maximum ratio that can be pumped against its own pressure by the steam, on the supposition that the velocity of steam issuing from the steam nozzle is as calculated for a reduction of pressure to 60 per cent., by a comparison of these two tables, it is seen that the limits of temperature of the feed water are soon reached with any injector. Thus, at 100 pounds absolute pressure the maximum ratio of water to steam is 11.5. By consulting Table III it is seen that that ratio is required for condensation purposes when the feed water has a temperature of about 125°, which would of course determine the limits of the injector, and this also agrees very well with the actual experiments.

The following table shows the limit of temperature of feed water, at which the perfect injector must fail, and the actual experiments showing the limit of failure of injectors in the experiment by Burwell and Arnold, on the supposition that the entering velocity of steam is 1400 feet per second.

Absolute Steam Pressure. Pounds per Sq. in.	Maximum Temp. of Feed Water. Theoret'cl F°	Maxim. temperature of feed water, experimental.				
		Hancock Inspirator. F°.	Park Injector. F°.	Metropol. Injector. F°.	Seller's Injector, from his catalog.	
					" 1876."	Old st'le
100	125°	. . .	. . .	. . .	*132°	110°
93	. . .	. . .	118°	. . .	. . .	. . .
90	129°	. . .	. . .	. . .	. . .	. . .
83	. . .	131°	. . .	123°	. . .	. . .
80	134°	. . .	. . .	. . .	130°	. . .
73	. . .	. . .	115°	. . .	. . .	. . .
70	138°	. . .	. . .	. . .	. . .	. . .
60	144°	. . .	. . .	. . .	130°	. . .
53	. . .	. . .	113°	. . .	. . .	. . .
50	150°	. . .	. . .	. . .	. . .	120°
40	156°	. . .	. . .	. . .	135°	124°
33	. . .	. . .	120°	. . .	. . .	. . .
30	162′	. . .	. . .	. . .	. . .	130°
20°	173°	. . .	. . .	. . .	138°	138°

* A manifest error.

These results can be computed from equations No. 20 and No. 22 A.

The ratio of water delivered for one of steam is,

$$Y = \frac{V}{\sqrt{2gh}} - 1. \qquad (22A.)$$

The minimum water delivered from equation (20) for use of steam.

$$Y = \frac{R - t''}{t'' - t'}. \qquad (20.)$$

These values would be equal at the instant of stopping the injector, and hence,

$$\frac{v}{\sqrt{2gh}} - 1 = \frac{R - t''}{t'' - t'}$$

From which, for a maximum,

$$t' = t'' - \frac{(R - t'')\sqrt{2gh}}{v - \sqrt{2gh}} \qquad (23.)$$

In this case t″ is the boiling point of water, at atmospheric pressure, h the head corresponding to the boiler pressure, R the heat in one pound of steam above zero.

The practical deduction from this discussion is that if the velocity of steam in the steam jet is 1400 feet per second, the injector as it exists in some of the best instruments, is as perfect as it can possibly be made. On the other hand, if the velocity of the steam entering is higher, there is a corresponding opportunity for improvement. It seems probable from this discussion that the velocity does not exceed 1600 feet, and that it is not less than 1400 feet, but special experiments have not, so far as the writer can learn, been made with sufficient accuracy to determine this point.

Errata in THE CRANK for November:

In equation 13 change + to − before $T_2 (\theta_1 - \theta_2)$, change

$$\frac{x_1 L_1}{T_2} \text{ to } \frac{x_1 L_1}{T_1}, \text{ and } p_2 - p_2 \text{ to } p_1 - p_2.$$

In equation 15, limits of integral are T_1 to T_2, and in equation following change sign of division to plus.

A METHOD FOR REDUCING CYLINDER CONDENSATION.

BY DANIEL ROYSE, M.M.E.

The three obstacles met with in attempting to increase the efficiency of the steam engine, are the narrow limits of temperature within which the fluid can be worked, the loss of heat by radiation, and the loss of heat by initial cylinder condensation and subsequent reëvaporation. Many engineers have devoted their attention to this third method of waste, and several plans for reducing it have been suggested. A description of one of these, that of Dr. Thurston, also the results of Mr. P. M. Chamberlain's experiments* upon the effect of the propoſed treatment in reducing the heat-trnsmitting power of cast-iron, and the results of Prof. Carpenter's experiments† upon the same subject, have been published in THE CRANK. The writer made further experiments and concluded that the maximum effect would be obtained by treating the iron with a 5 per cent solution of nitric acid for about ten days and then painting the surface with varnish or drying oil.

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* Vol. V, No. 1, p. 4. "A Practical Method for Reducing the Internal Wastes in the Steam Engine."—Thurston.

† Vol. V, No. 2, p. 3. "Heat Transmission Through Cast-Iron Plates Pickled in Nitric Acid."—Carpenter.

In this paper* are given the results obtained by thus treating the interier of the cylinder of the Payne engine in the Mechanical Laboratory. To determine the effect of the treatment two trials of the engine were made. After the first the piston and valve were removed, a block of wood fastened over the valve seat, the rubbing surfaces of the cylinder covered with paraffine, the cylinder-head replaced, and the cylinder filled with a 5% solution of nitric acid and allowed to stand for 12 days; the piston head being similarly treated for a like period. The acid and paraffine being removed, the heads, connterbores and steam passages painted with hard oil, and the piston and valve replaced, a second trial was made under as nearly as possible the same conditions as the first, and the results of the two compared. To investigate the transfer of heat taking place between the fluid and the metal walls, recourse was had to Hirn's Analysis.

A complete description of the apparatus, with illustrations, and the method of observing the data; also the theory of the analysis will be found in Vol. VI, No. 1, of THE CRANK, and need not be repeated here. Each indicator diagram was divided and measured, and the M. E. P. of the whole and of each part found and tabulated, then the analysis was applied to the several means of these quantities.

The "sensible," "internal latent," and "external latent," "heats" of one pound of steam at a pressure per square inch of P, are denoted by S, I, and E, respectively; the "latent heat," by $L = I + E$, and the "total heat," by $H = L + S$. The symbols X for quality, t for temperature, and C for volume in cubic feet of one pound at the pressure P will be used. In considering steam in the steam-chest, no subscript will be used with the letters H, L, S, E, P, t, X, and when the fluid at some other point is meant it will be indicated by attaching the proper subscript, as follows: 1 at cut-off, 2 at release, 3 at beginning of compression, 0 at beginning of admission, g for condensed steam, i for injection water, k for discharge water, j for steam in exhaust, and x for steam of the pressure at which the calorimeter takes it. V_c denotes the volume of the clearance, and $V_c + V_0$, etc., the volume occupied by the working fluid up to the point of the cycle indicated by the subscript attached to the second V. The meaning of other symbols will be evident from the context.

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* "A Practical Method for Reducing Initial Cylinder Condensation: A Thesis."—Royse.

To the weight of the condensed steam is added the weight of that which escapes through the calorimeter during exhaust, and the total is divided between the head and crank ends of the cylinder in proportion to the work done. The condensing water, G, is similarly apportioned on the basis of heat sent to the condenser.

TABLE I.

DATA AND RESULTS.

Diameter of cylinder, 6.06 in. Stroke, 8 in.
Volume cylinder, head end, .13354 cubic feet.
" " crank end, .12921 " "
Volume clearance, head end, .01744 " "
" " crank end, .01616 " "
Clearance, per cent. of stroke, head end, 13.06.
" " " " crank end, 12.51.

TRIAL.	First.	Second.
Absolute pressure in steam-chest, pounds	79.155	83.700
Quality of steam in steam-chest	.9941	.9799
Quality of steam in compression	1.0205	1.020
Steam used during run, pounds	716.424	586.704
Weight condensed steam per hour, pounds	259.92	234.00
Temperature of condensed steam	103.475°	95.060°
Weight of condensing water per hour, pounds	5044.878	6091.62
Temperature of condensing water, cold	42.758°	52.065°
Temperature of condensing water, hot	92.219°	87.555°
Revolutions per hour	11890.20	12393.60
I. H. P., head	3.3152	3.1763
" " crank	3.3054	3.3351
" " total	6.6206	6.5114
Brake horse power	4.7100	4.9094
Pounds of steam per I H. P. per hour	39.351	36.041

DATA AND RESULTS—*Continued.*

TRIAL.	First.		Second.	
	Head.	Crank.	Head.	Crank.
Cut-off, per cent. of stroke	18.963	20.544	19.143	21.843
Release, " " "	94.971	93.958	95.715	94.977
Compres. " " "	39.770	52.341	37.714	52.153
Absolute pressure at cut-off, lbs	65.550	62.567	63.560	60.880
Absolute " " release	21.933	23.400	19.240	22.480
Absolute " " compress	4.533	5.233	5.080	6.800
Absolute " " admission	36.533	37.300	34.170	37.620
External work, B.T.U., admis.	32.8356	34.3079	33.3900	37.1176
External " " expan.	64.1862	58.9474	59.0194	57.8289
External " " exh'st.	— 3.1300	— 4.8242	— 4.5970	— 7.5335
External " " comp.	—21.9711	—17.7220	—22.5895	—18.9893
External " " total	70.9207	70.7090	65.2229	68.4237

TABLE II—DATA AND RESULTS PER 100 STROKES.

QUANTITIES.	Symbols.	FORMULAE.	FIRST.		SECOND.	
			HEAD.	CRANK.	HEAD.	CRANK.
Steam used by calorimeter, lbs.	M_x		.00490		.00545	
Steam from boiler, lbs.	M		1.09707	1.09383	.91623	.97722
Steam in clearance, lbs.	M_o	$100\frac{V_c+V_o}{C_o X_o}$	.16458	.14414	.14346	.14540
Steam, total, lbs.	$M+M_o$		1.26165	1.23797	1.05969	1.12262
Heat of condensed steam	K'	$(M-M_x)S_k$	78.0629	78.1815	57.4338	61.6235
Condensing water, lbs.	G		21.2016	21.2274	23.7114	25.4396
Heat given to condensing water	K	$G(S_k-S_i)$	1048.6523	1049.9284	844.5176	902.8514
Heat supplied to engine	Q	$M(XL+S)$	1285.2743	1281.4785	1062.8957	1133.6487
Sensible heat at admission	H_o	$M_o S_o$	37.9982	33.4579	32.5093	33.8271
Internal heat at admission	H_o'	$100\frac{V_c+V_o}{C_o}I_o$	143.5501	125.5798	125.5173	126.5534
Sensible heat at cut-off	H_1	$(M+M_o)S_1$	338.3488	328.2161	281.9831	295.4915
Internal heat at cut-off	H_1'	$100\frac{V_c+V_1}{C_1}I_1$	545.5026	528.1695	534.8858	531.3785
Sensible heat at release	H_2	$(M+M_o)S_2$	254.4084	254.0300	206.1891	227.8784
Internal heat at release	H_2'	$100\frac{V_c+V_2}{C_2}I_2$	701.1183	706.5868	626.7889	688.2081
Sensible heat, beginning of compression	H_3	$(M_o+M_x)S_3$	21.3924	19.0826	19.5355	20.8868
Internal heat, beginning of compression	H_3'	$100\frac{V_c+V_3}{C_3}I_3$	113.9140	103.6313	131.0014	131.9348
Cylinder loss during admission	Q_a	$Q+H_o+H_o'-H_1-H_1'-\frac{W_a}{778}$	551.1356	549.8245	370.6544	430.0416
" " " expansion	Q_b	$H_1+H_1'-H_2-H_2'-\frac{W_b}{778}$	−135.8615	−163.1786	−75.1285	−147.0454
" " " exhaust	Q_c	$H_2+H_2'-H_3-H_3'-K-K'-\frac{W_c}{778}$	−303.3649	−285.3828	−214.9133	−193.6763
" " " compression	Q_d	$H_3+H_3'-H_o-H_o'-H_x-H_x'-\frac{W_d}{778}$	−29.7279	−18.6036	9.0961	11.4304
Heat discharged, and work	B	$K+K'+H_x+H_x'+\frac{W}{778}$	1203.0930	1198.8189	973.1920	1032.8986
Loss	D	$Q-B$	82.1813	82.6596	89.7087	100.7501
Loss	D'	$Q_a+Q_b+Q_c+Q_d$	82.1813	82.6595	89.7087	100.7501

TABLE III—SUMMARY AND RESULTS.

QUANTITIES.	Symbols.	FORMULAE.		FIRST.		SECOND.	
				HEAD.	CRANK.	HEAD.	CRANK.
Quality of steam entering	X	per calorimeter,	per cent.	99.41	99.41	97.99	97.99
Quality of steam at cut-off	X_1	$100\frac{V_c+V_1}{(M+M_0)C_1}$	“	52.34	51.50	60.986	57.045
Quality of steam at release	X_2	$100\frac{V_c+V_2}{(M+M_0)C_2}$	“	65.34	65.26	66.048	69.953
Quality of steam at compression	X_3	$100\frac{V_c+V_3}{(M_0+M_x)C_3}$	“	71.75	77.16	94.318	98.338
Quality of steam at admission	X_0	per calorimeter,	“	102.05	102.05	102.00	102.00
Quality of steam in exhaust	X_5	$\left(\frac{K+K'}{M-M_x}-S_5\right)\div L_5$	“	90.214	90.195	86.328	85.996
Heat lost, admission	*a*	$Q_a\div Q$	“	42.881	42.905	34.872	37.934
Heat restored, expansion	*b*	$Q_b\div Q$	“	10.571	12.733	7.068	12.962
Heat rejected, exhaust	*c*	$Q_c\div Q$	“	23.603	22.270	20.220	17.084
Heat lost, compression	*d*	$Q_d\div Q$	“	−2.313	−1.452	.856	1.008
Heat utilized, work	*w*	$\frac{W}{778}\div Q$	“	5.518	5.518	6.136	6.036
Heat lost, radiation	*r*	$D\div Q$	“	6.394	6.450	8.440	8.887
Ratio, radiation to work		$r\div w$		1.1588	1.1689	1.3755	1.4723
Ratio, cyl. condensation to work		$a\div w$		7.7711	7.7757	5.6318	6.2843
Thermodynamic efficiency	E	$(t-t_3)\div(461+t)$	per cent.	19.921	19.031	19.715	16.546
Actual efficiency	E_1	$\frac{W}{778}\div Q$	“	5.518	5.518	6.136	6.036
Efficiency compared with ideal	E'	$E_1\div E$	“	27.67	28.99	31.12	36.48

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TABLE IV.

General Summary.

Quantity, Percentages.	Symbol	First.	Second.
Heat lost by initial condensation	*a*	42.893	36.453
Heat restored during expansion	*b*	11.651	10.115
Heat rejected during exhaust	*c*	22.937	18.601
Heat lost during compression	*d*	— 1.883	.935
Heat lost by radiation	*r*	6.422	8.671
Heat utilized, work	*w*	5.518	8.084
Quality of steam at cut-off	X_1	51.920	59 016
Quality " " release	X_2	64.300	68.000
Quality " " begin. comp.	X_3	74.455	96.328
Quality " " begin. admis.	X_0	102.050	102.000
Quality " in exhaust	X_5	90.205	86.162

In computing the preceding table the quantity of heat transferred during each portion of the cycle was taken for the whole engine, *i. e.*, that in the head end plus that in the crank end, was divided by the total quantity of heat supplied to the engine, thus giving the quantities *a*, *b*, *c*, *d*, *r*, *w*, in percentages of heat supplied, and making the two runs comparable.

It is seen from Table IV that the effect of the treatment applied was to *reduce* the initial condensation 6.44 per cent., the reëvaporation during expansion 1.536 per cent., the reëvaporation during exhaust 4.336 per cent.; and to *increase* the cylinder loss during compression 2.818 per cent., the radiation 2.249 per cent., and the work .566 per cent. of the total heat supplied to the engine. At the same time the quality of steam at cut-off was increased 7.096 per cent., at release 3.700 per cent.; at beginning of compression 21.87 per cent., and the quality in exhaust decreased 4.043 per cent.; while the quality at admission remains practically unchanged. As would be expected, the quality of steam at cut-off and compression is improved, because of the diminished condensation and reëvaporation. That the loss by radiation should be increased is natural, from the fact that the heat transmitting power of the surface is decreased and such heat as passes it experiences greater difficulty in returning, and therefore a greater portion is radiated.

The steam consumption in the second trial was $.9799 \times 36.0413 \div .9941 \times 39.351 = .903$ of what it was in the first, and the work done was $6.084 \div 5.518 = 1.1026$ of what it was in the first; the increase in the economy of the engine effected by the treatment being 10 per cent.

ELECTRICAL MEASUREMENTS.*

III.

VOLTAMETERS AND CALORIMETERS.

The use of the voltameter for current measurement depends upon a law of electrolysis due to Faraday. (1834.)

(1) The amount of an electrolyte decomposed is always proportional to the current and to the time.

(2) The amount of matter liberated at each electrode is proportional to its "*chemical equivalent.*"

This law means that there can be no transfer of electricity through an electrolyte, without decomposition of the latter. Our means of detecting the existence of an electric current are so delicate that long before the changes due to electrolysis are noticed the galvanometer indicates current. Polarization, however, which is a sign of electrolysis already accomplished, shows itself wherever current has traversed an electrolyte.

In order that electrolysis may be used for the exact determination of current, the following conditions must be fulfilled:

(1) One of the products must be insoluble in the electrolyte.

(2) It must appear in a form easily collected, dried and weighed.

Almost the only materials which have been found available in practice are

H and O	from	H_2O.
Cu	"	$Cu\ SO_4$.
Ag	"	$Ag\ NO_3$.
Zn	"	$Zn\ SO_4$.

In all of these cases, the conditions are imperfect.

The Water Voltameter.

In the water voltameter, the following difficulties must be overcome:

(1) H and O are soluble in H_2O.

(2) H and O are occluded by the metallic electrodes.

(3) By-products are formed—chiefly, SO_3, H_2O_2, and Ozone.

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* Notes on lectures delivered to Seniors and Graduate Students by Dr. E. L. Nichols. The limitations of time and space have made it necessary to give an incomplete summary of the lectures given. Some lectures, indeed, are omitted altogether from this abstract.

(4) By katalysis, the gases formed may combine with other gases previously occluded by the metal.

The most accurate work done with the water voltameter has been done by Bunsen. He met the above difficulties by methods such as would be apt to occur to a chemist. Briefly stated, the features of his method were as follows:

(1) The products of electrolysis, H and O, were allowed to escape, their amount being determined by the loss of weight of the electrolyte—other observers had collected and weighed one or both gases. To prevent the carrying away of water undecomposed, the gases were passed through drying tubes which were also weighed before and after.

(2) To reduce absorption to a minimum, electrolysis was carried on at high temperatures (circa. 60° C.), and in a liquid nearly saturated beforehand with the two gases.

(3) Occlusion was prevented by forcing the electrodes to take up the gases to their full capacity before the beginning of the experiment.

(4) Katalysis of the gases was prevented by the amalgamation of the platinum electrodes, which process, also, greatly reduced the power of occlusion.

Handled in this manner, the water voltameter became an instrument of considerable precision, but under ordinary conditions it falls far behind both voltameters in which copper or silver are are used.

Copper and Silver Voltameters.

The copper voltameter, of these two, commends itself on the score of cheapness. It is generally considered to be somewhat less accurate than the silver voltameter, but we know its sources of error much more thoroughly and how these are to be met.

When a copper voltameter has been in the galvanic circuit for a considerable time and the plates are dried and weighed, it is found that the loss and gain are not equal.

Sources of error are:

(1) Solution of the electrodes by the electrolyte.

(2) Oxidation of the electrodes.

(3) Loss of copper by failure to form an adherent coating.

These side processes go on at rates which depend on the temperature of the solution, the amount of free acid present, and the current density. Gray* has shown that under like conditions as to solution and temperature, there is a definite *apparent* change in the electro-chemical equivalent of copper, with the current density.

---

* Gray; *Phil. Mag.*, 22, p 389 (1886); 25, p. 179 (1888).

This fluctuation is only apparent, and Professor Ryan[*] has shown that with the "spiral coil" voltameter it is much smaller than with the old forms. A very recent paper by Vanni[†] indicates that it may be further reduced by the dimunition of the free acid in solution.

The largest current-density for which an adherent coating may be obtained in the case of the plate voltameter, has been found to be about 7 amperes per square decimeter of surface, the plates being 1.5 centimeters apart.

The chief difficulty in the use of the silver voltameter lies in the fact that the losing plate is rapidly disintegrated, and that particles of silver are apt to be transferred to the gaining electrode by the action of gravity. The deposit is crystalline and not entirely adherent, but it is insoluble and free from oxidation. For these reasons it is not so difficult to obtain concordant results with the silver voltameter as with the copper voltameter.

The Electro-Calorimeter.

The principle upon which the calorimeter may be used for current measures is Joule's law

$$W = C^2Rt,$$
$$qJ = C^2Rt = CEt,$$

where q is the heat generated (in calories) and J is Joule's equivalent.

The two points which need especial mention are the determination of the water equivalent of the calorimeter and the measurement of the resistance of the wire in which the heat is generated. As to the water equivalent, it should be noted that unless the calorimeter be chiefly of metal, with thin walls, the observed value will not agree closely with the value calculated from the masses and specific heats of the parts. It is better, therefore, to obtain the water equivalent by calibration.

The resistance of the wire within the calorimeter cannot be determined beforehand by bridge-measurements, for its resistance is a function of temperature; and the very fact that the wire delivers heat to the liquid in which it is submerged, shows that it is maintained at higher temperature by the current. This temperature difference cannot be neglected. It is indeed often very large. The best way is to determine the resistance of the wire as a function of the current flowing, is by the "fall of potential" method; the conditions within the calorimeter being as nearly as possible those which are to exist when the latter is used for the measurement of current. The resulting curve will be of the general form shown in figure 4, from which for any given current traversing the calorimeter circuit, the resistance of the wire may be ascertained.

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[*] Ryan; *Trans. Am. Inst. E. E.*, Vol. VI, p. 322, 1889.

[†] Vanni; *Ann. der Physik*, Bd. 44, p. 215, 1891.

In constructing an electro-calorimeter for use in any given circuit, the resistance which will give highest effect may be determined as follows:

Let R_c be resistance within the calorimeter, R_b be resistance of outside circuit; we have,

$$W = C^2 R_c, \quad C = \frac{E}{R_b + R_c}$$

$$W = \frac{E^2 R_c}{(R_b + R_c)^2}$$

$$\frac{dW}{dR_c} = \frac{E^2 (R_b + R_c)^2 - 2\,E^2 R_b R_c - 2\,E^2 R_c^2}{(R_a + R_c)^4}$$

$$\frac{dW}{dR_c} \cdot \frac{(R_b + R_c)^4}{E^2} = (R_b + R_c)^2 - 2\,R_b R_c - 2\,R_c^2$$

$$= R_b^2 + 2\,R_b R_c + R_c^2 - 2\,R_b R_c - 2\,R_c^2.$$

When $\frac{dW}{dR_c}$ is 0, the maximum is reached; under which conditions,

$$R_b = R_c.$$ for max rise in temp in calorimeter

IV.

STANDARDS OF ELECTRO-MOTIVE FORCE.

When one has at command accurate resistance standards and a good tangent galvanometer, he is in possession of a better means of standardization for E. M. F. than can be obtained from any galvanic cell. It is, however, often convenient to use standard cells for purposes of calibration. Such cells are divided into *open circuit batteries* and *closed circuit batteries*.

Of closed circuit batteries none has been so thoroughly studied as the *Daniell cell*.

3 Methods of measuring E.M.F

{ Galv comparing [illegible]
Electrometer
Condenser [illegible]

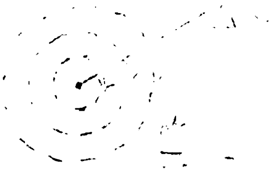

Fig. 1

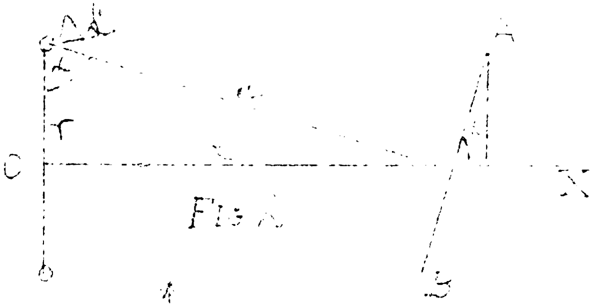

Fig 2

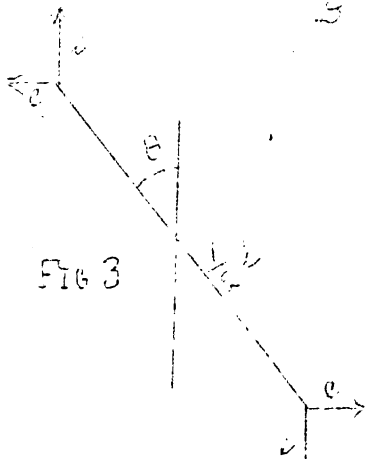

Fig 3

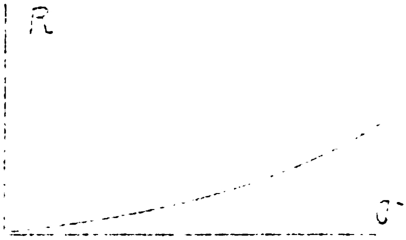

Fig. 4

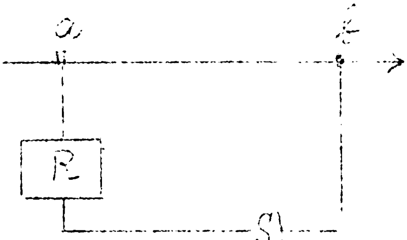

Fig. 5

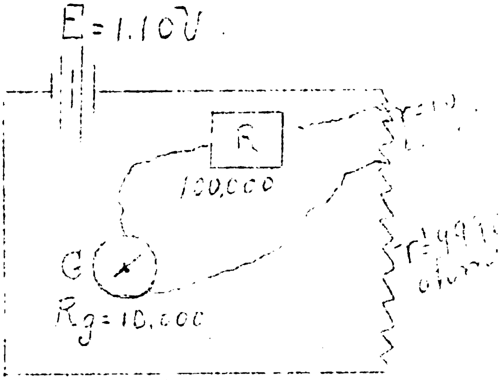

Fig. 6

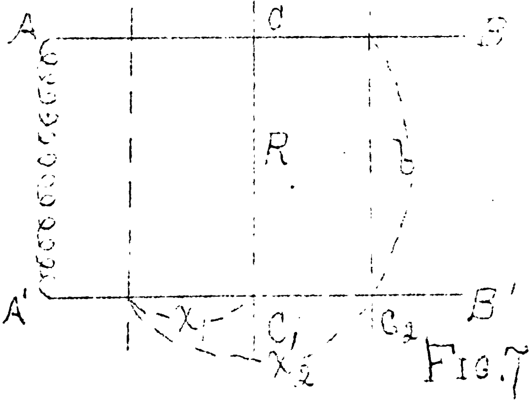

Fig. 7

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ASTOR, LENOX
TILDEN FOUNDATION

The conditions of constancy are :

(1) Freshly amalgamated zinc.

(2) Standard solutions of $ZnSO_4$ and $CuSO_4$.

(3) Copper, the surface of which is free from oxide.

The effective means of fulfilling the last named condition, which is most important, is to close the circuit for a time sufficient to coat the copper pole with freshly deposited copper.

For an *approximate standard* the Daniell cell has great advantages, viz.: It has a small temperature coefficient; it can be used freely on closed circuit; fluctuations in the state of the solutions produce no marked change in the electro-motive force of the cell.

When we look for high accuracy, however, the three conditions just mentioned must be carefully fulfilled. Various devices have been used to secure this end. The importance of the precautions prescribed may be seen from the following statements by Carhart.*

"The smallest deposit of copper on the zinc, due to diffusion of the copper salt into the zinc sulphate, lowers the E. M. F. 2 or 3 per cent."

"Even slight oxidation [of the copper], indicated by brown spots, raises the E. M. F. by as much as four parts in 1000, while a film of dark brown oxide may affect the E. M. F. as much as 2 per cent."

Devices for the prevention of diffusion, raise the internal resistance of the cell to a point at which its influence as a closed circuit battery is small. For open circuit work Clark's standard cell is on many accounts to be preferred.

The elements of the Clark cell are,

Zn (pure) — $ZnSO_4$ — Hg_2SO_4 — Hg (pure).

Prepared with pure materials and with a knowledge of the conditions to be met, these cells show great uniformity of E. M. F.

These conditions are :

(1) Concentrated $ZnSO_4$.

(2) Hg_2SO_4 (free from $HgSO_4$ or from any of the basic sulphates of mercury which are liable to form.

(3) Pure mercury.

(4) A form of cell which prevents the mercury from reaching the zinc.

The objections to the Clark cell are :

---

* Primary Batteries, p. 102, etc.

(1) It is constant only in open circuit and cannot be used in calibrations requiring the development of an appreciable current.

(2) The E. M. F. changes considerably with the temperature. Rayleigh found the temperature change to be expressed by the following equation:

$$E = 1.435[1 - 0.00077(t - 15^\circ)]$$

(3) The cell is not fairly portable.

Carhart has found means of partially obviating the two last objections by securing a really constant $ZnSO_4$ and by interposing a plaster diaphragm between the zinc and mercury electrodes.

V.

ELECTRICAL RESISTANCE.

Methods of measurement (aside from the well known "Wheatstone's bridge" method) to be discussed, are those applicable to very low resistances and to very high resistances. For very low resistances the "fall of potential" method gives good results. The galvanometers should be a sensitive one, to be used in the shunt circuit, and a standard galvanometer for large currents.

Let the specimen to be tested lie between *a* and be *b*, Fig. 5, and let it be traversed by a current from some constant source. This current, C, is to be measured by means of a standard galvanometer. G is a sensitive galvanometer in series with a resistance box R. The resistance of the shunt circuit should be very large compared with the resistance to be measured. If these conditions are fulfilled we have,

$$C = \frac{E_{(ab)}}{R_{(ab)}}$$

If $R_{(ab)}$ is very small, $E_{(ab)}$ will in general be a small fraction of a volt.

The best method of calibrating G, so that its reading will indicate $R_{(ab)}$, is to loop it around a known resistance, which will, in general, be much larger than $R_{(ab)}$ since it must be accurately measurable upon the Wheatstone bridge. The current through this known resistance, and the resistance of the galvanometer circuit are so varied as to give a deflection θ_s which is nearly of the size of $\theta_{(ab)}$ obtained in the test. If R_s, C_s, and R_g' are the values of the standardizing resistance, the standardizing current, and the new resistance of the galvanometer circuit, we have for $R_{(ab)}$:

$$R_{(ab)} = R_s \cdot \frac{C_s}{C_{(ab)}} \cdot \frac{R_g}{R_g'} \cdot \frac{\theta_{(ab)}}{\theta_s}$$

The object of this adjustment is to bring $\theta_{(ab)}$ nearly to unity, thus eliminating the θ_s, peculiarities of the galvanometer. In cases where the range thus obtained is insufficient, the law of the galvanometer may be determined and ratio of the currents corresponding to $\theta_{(ab)}$ and θ_s which may have widely different values, may be read. We have three ratios in this equation which may be varied through wide range, so that the method is limited only by the delicacy of the galvanometer.

In the measurement of any high resistances, as, for example, that of the insulation of a wire, the requisite is a galvanometer capable of indicating minute currents. Its resistance should be high.

The method of calibration is to obtain the figure of merit by use of as small a known E. M. F. as is obtainable, with large resistances in circuit, and then to test with as high a source of E. M. F. as can be accurately measured. The best source of E. M. F. for calibration is obtained by the method of standardizing for low resistances just indicated, a known current being passed through a known resistance, around which the galvanometer is shunted. In ordinary practice, however, a standard cell is used, for E. M. F., the galvanometer being looped around any desired portion of the resistance in the circuit, which resistance, together with that of the entire circuit, must be known, as well as the E. M. F. of the cell.

The arrangement in the diagram, which would be suitable for a galvanometer of the very highest attainable sensitiveness, would give the deflection to be expected for a current of $10.^{-10}$ amperes.

Such a galvanometer, used in a circuit with 100 volts, would give the same deflection as that obtained in the calibration, if it were acting through 10000 megohms of resistance. In these methods I have neglected altogether the use of galvanometer shunts, because, although these are very convenient devices, and allow the extension of galvanometer practice over very wide ranges, they are liable to introduce important errors, and should only be adopted where complete temperature control is practicable. The influence of temperature upon resistance is indeed a matter of the very highest importance in every operation of accuracy.

VI.

THE DETERMINATION OF THE OHM.

Before the introduction of absolute units in electricity, two practical units had become well nigh universal. One of these was the "Daniell," being the E. M. F. of a Daniell cell of stated construction; the other was the "Siemen's unit" of resistance, being the resistance of a column of mercury 1 meter long and 1 square millimeter in cross-section at O°C.

The use of such a mercury column, in the definition of standards of resistance, has not been given up with the introduction of the C. G. S. system of units. The specific conductivity of the solid metals varies to such an extent with the temper and also by reason of traces of impurities, which it is impossible to exclude, as to render them poor standards from which to determine resistance. Mercury being a liquid, may be purified by distillation, and it of course possesses no *structural* peculiarities as the result of previous treatment. The problem of the determination of the ohm at the present day consists in finding the length in centimeters of a column of mercury 1 mm. in cross-section, which will possess the defined amount of resistance.

The theoretical conception of resistance, however, is that of a *velocity.*

Suppose a straight conductor free to move on parallel horizontal tracks of negligible electrical resistance.

In Fig. 7—Let H be the horizontal intensity of the magnetic field, q the quantity of electricity induced by moving R from C_1 to C_2,

$$Rq = Hb(x_1 - x_2) = HS,$$

where S is the area described by R. Now, since q = Ct, we have

$$R = \frac{HS}{q} = \frac{HS}{Ct}$$

H may be expressed in C. G. S. units by the method of Gauss, S may be found in centimeters, and t in seconds.

To obtain C in absolute measure, suppose R to be maintained at a constant velocity v, travelling through a uniform field, and that the current be sent through a tangent galvanometer. We have:

$$S = Bvt$$

$$RCt = HS = Hbvt$$

$$R = \frac{Hbv}{C}$$

By means of the galvanometer:

$$C = \frac{r^2 H}{L} \tan \theta,$$

$$\therefore \; R = \frac{bL}{r^2 \tan \theta} \cdot v \cdot$$

Let the velocity be such that tan θ is unity, and let $bL = r^2$. Then R = v.

In 1862 the British Association appointed a committee to determine electric resistance in absolute measure, and to report upon a practical unit. The method adopted, following a suggestion of Sir William Thomson's, was based upon the consideration just presented. It had been proposed by W. Weber of Göttingen, in the course of his classical work on absolute measurements in electro-dynamics. A pair of coils, each 15.8 c.m. radius, with 156 turns, were driven with uniform rotation in the earth's field, and the action of the induced current upon a weak magnet of slow period, situated at the center of the coils, was noted.

The result was that 104.83 centimeters of mercury, 1 m.m. in cross-section, which corresponded to the absolute unit, multiplied by 10^9, became the B. A. of unit of resistance, known as the B. A. ohm.

Many redeterminations have since been made and it is now known that the true value of the ohm is 106.3 ± c.m of mercury. The second place of decimals is still in doubt.

In 1881–82 Lord Rayleigh repeated the B. A. determination and found 105.95, 106.25. H. F. Weber, in 1884, found by same method, 106.16. Joule, 1866, by the calorimeter using the equation $R = \frac{W}{C^2 t}$ obtained 106.22.

L. B. Fletcher (1885) by a modification of Joule's method, in which the difference of temperature between the wire and the water of the calorimeter was taken cognizance of, (a point brought out in Lecture II), found 105.95.

The earth inductor and ballistic galvanometer, introduced by Wilhelm Weber in 1848, have frequently been used for the determination of the ohm. To mention only recent work, G. Wiedemann, in 1884, found the value to be 106.18; Kohlrausch, 1884, obtained 105.91; Mascart, Nerville, and Benoit, 1884, 106.37.

In 1878 Rowland introduced the method of making and breaking circuit in a neighboring coil, a method which has given very accurate results.

Rowland, in 1878, obtained 106.16; Glazebrook, in 1882, obtained 106.29; Kimball, in 1883, obtained 106.25; Mascart, Nerville, and Benoit, in 1884, obtained 106.30; Rowland and Kimball, in 1884, obtained 106.31.

Other methods, such as the production of a permanent deflection by means of a series of induced currents, or the observation of the dampening of a galvanometer needle, have been employed, but not with so accurate a result.

SIBLEY COLLEGE LECTURES ON THE FINE ARTS.

Lectures on Art constitute one of the regular Sibley College courses by non-resident lecturers; but they are also in part given by our own talented instructors in that department. They were inaugurated, with the approval of the University authorities and the Director, by Professor Cleaves, two years ago, and a very interesting and able discussion of the "Old Masters" by Professor Gutsell, in a series of four or five lectures, on Saturday evenings in the Spring term, has been made the introductory of the later and more extended courses. Last year a course by Mr. Gutsell was begun but was interrupted by a succession of accidents and misunderstandings and it was then too late to complete the course as planned. This year the course has been commenced promptly in the first term and is likely to prove a source of exceptional pleasure and instruction to lovers of art, as it is expected to continue through the college year.

The first lecture of the course was delivered on Saturday evening, Nov. 21, in Barnes Hall, by Professor Fenallosa of the Museum of Fine Arts of Boston. In spite of a driving rain, a "full house" greeted the lecturer, who held their attention and was listened to with intense interest for nearly an hour and a half. The speaker is an art-critic, a connoisseur, and an authority. His lecture was a most thoroughly philosophic discussion of the aspects, historically and æsthetically, of the past and the present in the art of the orientals. For this study, he is probably the best equipped man in this or any other country.

Mr. Fenallosa is a graduate in Philosophy, (Harvard '74,) and of post-graduate courses both in this department and in Æesthetics. Later he studied art and became distinguished for his work. He was elected by the Japanese government to aid in the promotion of art in that country, after having gone there as a Professor of Philosophy in the Imperial University. He gave eight years to the history of Chinese and Japanese art, and was so fortunate as to be able to recreate that department from original documents running back 1,200 years. He went to Europe with a Japanese commission, the only foreign member, studying art for the main purpose of promoting the fine arts and industries. He organized the Japanese National Art Museum and a National Art Academy, becoming the manager of each. He returned home in 1890 to take charge of the wonderfully extensive and complete Japanese collections of the Boston Art Museum and still continues his work there. His lecture was a philosophical and historical study of oriental art as developed during the twenty-five centuries preceding the present. He traced the growth of its earliest germ, with many vicissitudes, as alternating periods of war and peace checked or impeded its progress, from its incipiency in Chinese barbarism through a number of periods of prosperity and, sometimes, of extraordinary perfection, to contemporary and familiar methods of work and conventional forms. The art-contagion was transmitted to Corea and to Japan at some time subsequent to the Christian era and has now for several centuries been most advanced by the Japanese. This progress was well and curiously illustrated by a graphical construction on the blackboard, the intermittent rise and fall of art being shown by a curve sketched on the board; its co-ordinates being centuries and art-progress.

The inauguration of the course was thus most gratifying, both in the character of the lecture and in the attendance; the audience including the most cultivated among the Faculty, a large delegation of art-loving students from Sage College—ladies forming, in fact, a very large part of the audience—and some of the most earnest and wide-awake students, not only of Sibley College, which was well-represented by both students and instructors, but of the University at large. It is announced that the course will be continued by lectures from distinguished artists, engravers, and critics, and by home talent as well. It is understood that Mr. Gutsell is preparing a series of at least three or four lectures to be incorporated into the list, and possibly others of the little coterie of artists in Sibley College and near at hand may be induced to contribute to the pleasure and profit which such a course may be expected to give. It is a pleasure to note that the best men in Sibley College and in other technical departments appreciate this, which is one of the most admirable of their many unexampled opportunities for general as well as professional culture. This once small body of brightest minds is now rapidly and steadily growing, and already does much to stimulate a love of real culture among the more purely, but not less earnest, utilitarians, with whom such an institution naturally abounds.

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AN ENGINEER'S ESTIMATION OF THE CRANK.

A few days ago there was received from one of the most prominent engineers of New England, a letter which so clearly approved of the policy of THE CRANK, that we have taken the liberty of publishing the following extract. * * * "I would say that I must express my agreeable surprise at the fact that such an able technical magazine, as THE CRANK, should be published by any institution of learning. It is a pleasant and agreeable variation from the superficial and flippant tone of most of the college journals."

THE GRADUATE PIN.

At a meeting of Sibley seniors held on Tuesday, Dec. 1, the question of a graduate pin was discussed, and it was decided to adopt such a pin. The question of communicating with alumni and of selecting a design was left with a committee, R. T. Mickle, chairman. At a subsequent meeting of the committee, a number of good designs were submitted, but no action will be taken until next term. Meanwhile any good designs would be welcomed by the committee, and can be sent to Mr. Mickle, 58 North Tioga St.

THE PROVIDENCE MEETING OF THE A. S. OF M. E.

The meeting of the American Society of Mechanical Engineers, held at Providence during the summer, was in some respects the most notable in the history of that very successful society. The social features were unusually attractive, and a large number of papers of a high order were presented; a prominent part having been taken by college men. Dr. Thurston presented a paper on "Steam Engine Efficiences: The Ideal Engine Compared with the Real Engine," in which interesting comparisons are made between the ideal engine,—"that which is treated of in all purely thermodynamic studies of the engine as free from those wastes of heat and of power which distinguish the operation of the real engine,"—and the real engine, which is not only subject to the necessary thermodynamic waste by rejection of heat at the lower limit of expansion, but also wastes energy by conduction, radiation, internal transfer of heat without accompanying useful work, and by frictional loss of mechanical energy actually transformed from heat.

With the assumed cases of compound engines using steam at an absolute pressure of 250 pounds, condensing and non-condensing, it is shown that the real condensing engine gives the maximum efficiency with a ratio of expansion of about 18, and coal consumption of 1 15 pounds per H. P. per hour; while the corresponding ideal engine would expand about 32 time advantageously, using 1.13 pounds of coal.

For the non-condensing engine, the maximum ratio of expansion is about 8, and the corresponding ratio for the ideal case is about 11. The coal consumption for the two cases being 1.36 and 1.68 pounds per H. P. per hour, respectively.

Professor Carpenter contributed two valuable papers; one on the Application of Hirn's Analysis to Engine Testing and a Method of Measuring Directly the Quality of the Steam in the Clearance Spaces. In this he describes his very ingenious method of sampling the steam during any short period of the stroke. An abstract of this paper, written by the author, appeared in the October issue of THE CRANK. The other paper by Professor Carpenter was entitled Notes Regarding Calorimeters.

Professor Peabody of the Massachusetts Institute of Technology read a paper on the Application of Hirn's Analysis to Multiple-Expansion Engines. Professor Jacobus and Professor Denton of Stevens Institute presented papers also.

Mr. W. W. Bird contributed to the steam jacket question, giving a description of experiments made at the Worcester Institute.

Mr. J. T. Henthorn, of Providence, read a paper on the 500 H. P. Reynolds-Corliss triple-expansion engine of the Narragansett Electric Station. This engine has become famous for the wonderful performance with which it is credited by Mr. E. D. Leavitt and Mr. Henthorn. In a 10 hours' trial, it showed a consumption of only 12.96 pounds of steam per I. H. P. per hour, and this under some unfavorable conditions. It is believed that this engine can equal the performance of the triple expansion engine reported by Professor Schröter of Munich to have developed an indicated horse power on 12.6 pounds of steam.

IMPORTATION OF BOILER-FURNACES AS "FLUES."

A curious instance of the importance of exact terms in technical matters is to be found in the recent decision of the Treasury Department relating to boiler-furnaces imported as flues. "Flues" may be imported under a duty of 2½ cents a pound; but "furnaces" must pay a duty of 45 per cent. *ad valorem.* The Treasury Department decides, in the case of "Purves ribbed flue"—which is a ribbed cylindrical furnace—that it shall be admitted as a "flue," and the appraiser says: "Furnaces may or may not be set in the flues in question, but such use does not destroy the identity of the cylinders as boiler-flues." In a 'Manual of the Steam Boiler,' by Thurston, an eminent authority on the subject, he speaks of marine tubular boilers (page 363 and other pages) with furnaces in the flues.

The Department confirms this decision. Now it happens that corrugated boiler-furnaces are manufactured in this country, and, at the cost here of material and wages—about double that in Europe—the makers cannot stand very sharp competition, though using labor-saving machinery and ingenious forms of apparatus in the work. The imported furnaces above referred to come into direct and serious competition, as they are imported for this very purpose—in fact boiler *furnaces* are not imported, or separately built, in any other than this cylindrical form—and this decision may make or break an important industry.

The Continental Iron Works, the makers in question, have appealed from the appraiser and the decision of the Treasury Department, and the testimony of the author above referred to will be sought in the case. Oddly enough, although he uses the term flue very generally in the book quoted, and elsewhere, he also uses and prefers the other term, stating that, while both are used, the term "*furnace*" is the proper one; the part under discussion having for its principal function the enclosure of the fuel and production of heat, and *not* simply the transmission of gases. The object of the writers of the law was evidently to secure the domestic product against dangerous competition, as no other furnaces are imported or known to importers.

PERSONALS.

'91.

J. Herrick is in the Pennsylvania Railroad shops at Altoona, Pa.

G. R. Chamberlain is with an electric motor company in Alleghany, Pa.

C. E. Davis is at Newton, Mass., where he is engaged in work in sanitary engineering.

A. Louis Keuhmsted is in the expert department of the Thomson-Houston Electric Co., Lynn, Mass

J. E. Kress, one of last year's editors of THE CRANK, is in the draughting department of the Cambria Iron Co., Johnstown, Pa.

F. A. Barton has been commissioned Second Lieutenant in the United States army, and is now stationed at Fort Leavenworth, Kansas.

'92.

Jas. Tracy is with the firm of Whitney & Tracy, Toledo, O.

Chas. Pope is with the firm of E. C. Pope & Co., Cleveland, O.

J. R. Massey is with the Buckeye Electric Co., Cleveland, O.

J. Gleason is now superintendent of his father's machine shop at Rochester, N. Y.

A. H. Meyers is draughtsman for the Steam Laundry Machine Manufacturing Co., at Columbia, Pa.

Maurice Hoopes is superintendent of the Edison Electric Lighting and Railway plants in Westchester, Pa.

C. W. H. Blood is in a draughting office at Boston, Mass. He will remain out of the University for one year.

A. D. Morehouse, who has during the past year been working with an engineers corps in Nicaraugua, has returned to the University.

Joe M. Wolfe will not return this year, owing to the death of his father in August The latter was a Trustee of Bucknell University and a man widely known in Pennsylvania politics. Joe has been offered a position by Governor Beaver on the World's Fair, which he will accept.

CURRENT EVENTS.

'94 has adopted a class cane.

The new Gymnasium annex is now completed.

There are 66 candidates for the Freshman crew.

The foundations for the new Law building are laid.

Thanksgiving recess occurred Nov. 26 to 30 inclusive.

Damrosch's orchestra gives a concert at the Armory on Dec. 18.

The Masque gave two successful minstrel performances, Dec. 4-5.

Sibley College students will build a triple expansion engine to be exhibited at the World's Fair.

Judge Finch delivered his inaugural address as Dean of the Law School, on Wednesday, Nov. 18

There is considerable current discussion in regard to Cornell joining the Intercollegiate Football League.

A Thanksgiving Festival, for the benefit of the Cornell Ward in the Ithaca Hospital, was given at Barnes Hall on Thursday, Dec. 3. Over $400 were netted.

The third annual convention of the College Association of the Middle States and Maryland was held at Cornell, Nov. 27-28. President Low, of Columbia, was elected President of the Association for the following year. There was a large attendance.

At the Fifth Avenue Hotel, N. Y., on Nov. 30, the Intercollegiate Rowing Association met and elected officers, as follows: Prof Goodwin, of Columbia, Pres.; H. J. Hagermann, '94, Vice-Pres.; T. J. D. Fuller, '92, Sec'y ; Mr. Hunter, of U. of P., Treas.

Football :—Nov. 14, at Princeton, Cornell 0, Princeton 6 ; Nov. 17, at Percy Field, '94—14, '95—0 ; Nov 21, at Detroit, Cornell 58, University of Michigan 12; Nov. 24, at Detroit, Cornell 32, Detroit Athletic Club 0 ; Nov. 26, at Chicago, Cornell 4, University Club 12; Nov. 28, at Chicago, Cornell 10, University of Michigan 0. The game with the University Club at Chicago on Thanksgiving Day, was won by unfair playing, the University Club playing a brutal slugging game. Cornell's total score for the season is 298 against her opponents total of 34 points.

THE CRANK

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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

THE MILITARY ENGINEER AND HIS WORK.*

BY COL. W. R. KING.

It is not an easy matter to present a dry subject in such an attractive form as to excite a thrilling interest in it, and military science is no exception to this rule. An ingenious military instructor at one of our universities has succeeded in pointing out certain analogies between grand tactics and the festive game of football, which appears to have greatly improved the football, if we may judge from the recent victories of the blue over the red and the black and orange, but it is not so clear that the effect of the union has been very beneficial to military science; and even if such had been the case, I fear there are no similar analogies that would be useful in enlivening the subject of military engineering.

From the earliest times of which we have record man has been disposed to strive with his fellow man, either to maintain his own rights or to possess himself of some rights or material advantage enjoyed by others. When one or only a few men encroach on the rights of others in an organized community, they may be restrained by the legal machinery of the state, such as courts, police and prisons, but when a whole community or state rises against another, the civil law becomes powerless and a state of war ensues. It is not proposed here to discuss the ethics of this question, nor the desirability of providing a suitable court of nations for settling all international difficulties without war. The great advantage of such a system of avoiding war is admitted by all intelligent people. We notice here a singular inconsistency in the principles upon which this strife is carried on, viz: If it be a single combat, either a friendly contest or a deadly one, the parties are expected to contest on equal terms as nearly as may be arranged; but if large numbers are engaged, or in other words, when the contest becomes war the rule is reversed and each party is expected to take every possible advantage of his adversary even to the extent of strategem or deception. In fact it has passed into a proverb that "all things are fair in love and war."

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* A lecture delivered before the students of Sibley College, Cornell University, December 4, 1891.

Now one of the first things resorted to, in order to gain an advantage over the enemy, was to bring in material appliances, such as walls, ditches, catapults, scaling ladders, battering rams, and subsequently the more modern appliances, such as guns, forts and torpedoes, all of which are known as engines of war, and the men who built and operated these engines were very naturally called engineers. It is this kind of an artificer that Shakespeare refers to when he playfully suggests that "'tis the sport to have the engineer hoist with his own petard."

The early military engineer has left ample records and monuments of his genius. The walls of ancient cities, castles that still crown many hills in both hemispheres, the great Chinese wall, the historical bridge of Julius Caesar, which with charming simplicity he tells us was built because it did not comport with his dignity to cross the stream in boats, the bridge of boats across the Hellespont by Xerxes, are all examples of early military engineering. The Bible tells us "King Uzziah built towers at the gates of Jerusalem, and at the turning of the wall and fortified them." We may note in passing that the buttresses, battlements and bartizans with which our modern architects ornament or disfigure churches, peaceful dwellings and public buildings, are copied from the early works of the military engineer.

Coming down to the military engineers of our own country we find that one of the fist acts of the Continental Congress, after appointing Washington as commander-in-chief, was to authorize him to employ a number of engineers. It was not, however, until 1777, that a number of engineer officers from the French army arrived in this country, and were appointed in the Continental army. Gen. DuPortail was made Chief Engineer, and Col. Kosciusko, the great Polish patriot, was among his assistants. Other officers of the Continental army were employed on engineering duty; and under their supervision such works as the forts and the great chain barrier at West Point were built, and the siege operations around Boston and Yorktown were carried on.

After the close of the war in 1794, a Corps of "Artillerists and Engineers" was organized. This corps was stationed at West Point, and became the nucleus of the United States Military Academy. In 1802, by operation of the law reorganizing the army, this corps was divided, as the names would indicate, into an Artillery Corps and Corps of Engineers. The Corps of Engineers consisted of one major, two captains, four lieutenants and ten cadets. The Artillery Corps was again divided into the Ordinance Corps and several regiments of artillery, now five in number, while the duties of the Corps of Engineers were divided between the Engineer Corps and a Corps of Topographical Engineers, organized at a later date; but on the breaking out of the late Rebellion it was deemed best to unite these two corps, and they have so remained until the present time. The Corps of Engineers now consists of 118 officers of various grades, from Second Lieutenant to Brigadier General, of which last grade there is only one officer, the chief of the corps, and it requires something more than an average official life-time for the aforesaid lieutenant to attain that rank. Hardly one in ten of them ever reach it. Daniel Webster's remark to the young lawyer that "there is always room at the top" will not apply to the Corps of Engineers. The officers are all graduates of the Military Academy, which institution continued as a part of the Corps of Engineers until 1866. The vacancies in the corps are filled by the assignment to it of from two to six graduates each year, and there is attached to the corps a battalion of four companies of enlisted men, formerly called Sappers and Miners, but now known as the Battalion of Engineers.

We now come naturally to the duties of our military engineer, and here I may remark that these duties are so varied and so numerous that a detailed recital of them would suggest Goldsmith's "Village Blacksmith:"

* * * "And still the wonder grew,
That one small head could carry all he *ought to know.*"

[Never lose sight of fact for the sake of rhyme.] In general terms, his duties consist of:

1. Military surveys and explorations.
2. Boundary surveys.
3. Geodetic and hydrographic survey of the Great Lakes.
4. Building fortifications—both permanent works, and temporary or field works.
5. Constructing military roads.
6. Pontoniering or building military bridges, both with the regular bridge trains and with improved materials.
7. The planning and directing of siege operations, either offensive or defensive; sapping, mining, etc.
8. Providing, testing and planting torpedoes for harbor defence when operating from shore stations.
9. Staff duty with general officers.
10. Improving rivers and harbors.
11. The building and repairing of lighthouses.
12. Various special duties as Commissioner of District of Columbia, Superintendent Military Academy, Commandant Engineer School, instructors at both of these schools, attachès to several Foreign Legations, for the collection of military information, etc.

It would of course exceed the proper limits of a single lecture to go into the details of these many duties, but we may take only a passing glance at most of them and give more special attention to a few that may involve some points of interest. Perhaps the most interesting branch of the subject would be that of permanent fortifications, or what amounts to almost the same thing in this country, sea coast defenses. And here our trouble begins, for, while civil engineers have constant experience to guide them, their roads, bridges and other structures being in constant use, the military engineer has only now and then, at long intervals, a war or a siege of sufficient extent to furnish data upon which he can safely plan or build his structures. Imagine a civil engineer designing a bridge, road or a dam to meet some possible future demand, without having seen such a structure used for twenty years or more, and you can form some estimate of the delightful uncertainties that surround the military engineer when called upon to design a modern fort. The proving ground shows him that radical improvements are necessary, but actual service conditions are almost entirely wanting, and such as we have contradict many of the proving ground theories. Thus we have records of shot going through 25 inches of iron or 25 feet of concrete on the proving ground; but such actual service tests as the bombardment of Fort Sumter, Fort Fisher, and the forts at Alexandria contradict this entirely and indicate that, except for the moral effect, our old forts, with modern guns in them and some additional strengthening at their weaker points, would answer all purposes so far as bombardment from fleets is concerned. This is not saying that the forts are good enough in their present condition, but simply that they can readily be made far superior in strength, both offensive and defensive, to any fleet that could possibly be provided at anything like the same expense, or in fact at any expense that would be justified by the condition of our treasury, either past, present, or probable future. It might be added that a still more serious difficulty in the way of the military engineer, so far as practice and its consequent experiences are concerned, is that for many years past, until quite recently, there have been no funds either for experiments or actual work on fortifications, so that very little has been done on them during the last twenty years.

Without going into the question of the necessity for sea coast defenses, we may assume that an enemy is likely to come into one of our harbors and that it is desirable to keep him out. What provisions must be made to accomplish this, *i. e.*, to secure the safety of the harbors and the millions of dollars worth of destructible property concentrated at the great trade centers that are usually located upon those harbors? We must first take a look at the enemy and see what he is like before we can decide what will be needed to repel his attack. For this purpose we need not draw on the imagination, but we may simply examine some of the more recent armadas sent to bombard seaports. For example, the fleet sent by Great Britain to bombard the Egyptian city of Alexandria, in 1882. This fleet consisted of eight heavy iron clad ships of from 5,000 to 11,000 tons displacement, and five or six smaller vessels; and the armament of this squadron numbered more than one hundred guns of all calibers, from the sixteen-inch rifle down to the seven-inch rifle, besides several smaller guns. But this fleet represented only a small fraction of England's naval power. During some recent evolutions she turned out thirty-six heavy iron clads and forty smaller vessels and torpedo boats. The crews of these vessels numbered nearly 19,000 officers and men, or about three times the entire number in our navy. Such a fleet, or more likely a much larger one, might appear at the entrance say of New York harbor within ten days after a declaration of war, and demand whatever the nation to which it belonged might choose, with the alternative of bombardment.

The problem of protecting our people and property from such attacks is not a new one, and in fact most of the conditions of this problem remain the same as they were fifty years ago, the differences being in degree rather than in kind. The most natural thought would be to meet such a fleet by another fleet, but the folly of such a course will become apparent from a moment's consideration. The difficulties would be :

1st. Our fleet must be decidedly stronger than that of the enemy, or we simply fight a duel with an equal chance of success or failure.

2d. In such a duel the enemy would risk nothing but the loss of his fleet, and even a portion of that would be likely to escape, but we would not only risk a similar loss, but we would also lose the city or subject it to the payment of a heavy contribution to the enemy.

3d Unless we have a fleet for every harbor it would be impossible to depend upon this kind of defense, as the enemy would select whichever harbor he found least prepared to receive him. It would be of vital importance that we defend every harbor of importance, as a neglect to do so would be like locking some of our doors and leaving the others open to the burglars.

4th. It might be thought that we could send our fleet to intercept the enemy or blackade him in his own ports, but this has been found impracticable. Large fleets can readily escape from blackaded harbors, or elude each other on the high seas, and any such scheme implies that we are much stronger on the ocean than the enemy, which is very far from the case. To build a navy that would overmatch that of Great Britain alone would not only cost untold millions, but it would require many years for its accomplishment ; and even if this were done there would be nothing unusual in an alliance of two or more powerful nations, which would lead us again in the minority. *Fleets then cannot be relied on for permanent defense.*

Again it may be said that we have millions of the bravest soldiers in the world who could be assembled and placed under arms at a few days notice. This kind of defense would also prove a delusion, for a hundred acres of soldiers armed with rifles and field artillery would be powerless to drive away even the smallest iron clad or stop a single projectile from one. In fact neither of these plans nor both together would be much more effective than the windmills and proclamations which Irving humorously describes as the means adopted by the early Dutch Governors of New York to defend that city against the Swedes and Yankees.

Having considered some of the means of defense that will *not* answer the purpose, we may inquire what means *will be* effective. And here it should be noted, that our defenses should be so effective as not only to be reasonably safe, but to be so recognized by all nations and thus discourage, if not actually prevent an attack upon our coast.

In the first place, we must have heavy guns in such numbers and of such sizes as to overmatch those of any fleet likely to attack us. These guns must be securely mounted so as to be worked with facility and accuracy, and they must be protected from the enemy's projectiles at least as securely as his guns are from ours. Merely placing ourselves on equal terms with the enemy, as in case of a duel or an ancient Knight's Tournament will not answer, first, because such a state of things would invite rather than discourage attack, and secondly, because the enemy would have vastly more to gain by success, and vastly less to lose by failure than we would. This can be accomplished much easier than is generally supposed either by earthen parapets of sufficient thickness or by iron turrets or casements. It is evident that the weight of metal used in these structures may be vastly greater than could be carried on shipboard. Great weight of metal is no objection on land, but aside from its cost is a positive advantage. This is evident when we consider the enormous quantity of energy stored in the larger projectiles moving at high velocities. For example we often hear of the 16 inch rifle whose projectile weighs about one ton, and this enormous mass projected at a velocity of 2000 feet per second would have a kinetic energy of 60,000 feet tons, or it would strike a blow equal to that of ten locomotives of 50 tons each running at 60 miles an hour and striking a solid wall. Any structure designed to resist such ponderous blows must therefore have enormous weight or it will be overturned or driven bodily from its foundations. If the armor itself is not thick enough to give the required weight as well as resistance to penetration, the additional stability must be supplied by reinforcing it with heavy masses of metal or masonry. It is evident, therefore, that *quality* of metal is less important than *quantity*, and that so long as it is sufficiently tough to resist fracture, a soft cheap metal like wrought iron or low steel is better adapted for permanent works than any of the fancy kinds of armor that have been tested for naval purposes. As an illustration of this we may compare compound or steel faced armor with wrough iron as follows: The best of the former offers only about one-third greater resistance to penetration than the latter, or 12 inches of compound armor may equal 16 inches of wrought iron, but the cost per ton is nearly double, so that by using wrought iron we may have double the thickness or 24 inches which would give more than double the resistance to penetration in addition to giving double the stability against overturning or being driven bodily out of place. But our guns may be reasonably well protected by earthen parapets without any expensive armor by so mounting them that when fired they will recoil downwards or to one side so as to come below the parapet for loading. This method of mounting is called the disappearing principle and has been suggested by many engineers, some of whose designs date back more than 100 years. We may also mount our guns in deep pits, where they will be covered from the enemy's guns, and fire them at high elevation so that the shell will fall from a great height and penetrate the decks of the enemy's ships. This is known as mortar firing, but the modern ordnance used for this purpose is more of a howitzer than a mortar, being simply short rifled pieces arranged for breech loading. All our batteries should of course be as far from the city or other object to be protected as possible, to prevent the enemy from firing over and beyond the batteries into the city.

But with all these precautions the enemy might put on all steam and run by us either at night or in a dense fog and we must have some means of holding him under the fire of our guns until his ships can be disabled or driven away. This object is sought to be accomplished by the use of torpedoes anchored in the channels and under the fire of our guns so that they cannot be removed by the enemy. These torpedoes are generally exploded by electricity from batteries located in casements on shore, these casements being connected with the torpedoes by submarine cables. It is easy to see how the torpedo may be so arranged that when struck by a ship the electric current will be closed, and, if the battery on shore is connected at the same instant, an explosion will take place; on the other hand, if the battery on shore is disconnected a friendly ship may pass in safety over the torpedoes. Many ingenious contrivances have also been devised by which the torpedo may be made to signal back to the shore station either that it has been struck or that it is in good order for service, in case the enemy should undertake to run over it. One simple plan for this is to have a small telephone in the torpedo with some loose buck shot on the diaphragm, which is placed in a hortzontal position, and will be slightly tilted as the torpedo is moved about by the waves. By connecting the shore end of the cable with a telephone receiver the rolling of the shot may be distinctly heard if the torpedo is floating properly, but if sunk at its moorings or if the cable is broken, no sound will be heard.

The use of torpedoes involves the use of both electricity and high explosives, and a careful study based upon actual experiments has been carried on for many years, by the engineers and naval officers in all civilized countries. Some of these experiments have supplied interesting and useful data, for the use of the agents in questions, for various industrial purposes.

Another form of torpedo is that known as the locomotive torpedo of which there are several kinds: some are propelled by liquid carbonic acid which is carried in a strong tank and acts through a compact engine in driving the propeller. One of these is steered by electricity from the shore, and is known as the Lay-Haight torpedo and can run twenty-five miles per hour. The Whitehead torpedo is also propelled by liquid carbolic acid but is not steered from shore. Its depth is regulated by an automatic device actuated by the pressure of the water. The Howell torpedo is driven by a heavy fly wheel which is set in rapid rotation just before the torpedo is launched. It has but a short range and is intended for launching from ships. Another torpedo is propelled and steered from shore by rapidly pulling out of it two fine steel wires which, in unwinding, drive the twin screw propellers. This is the Brennan Torpedo. The Sims-Edison torpedo is both propelled and steered by electricity from the shore, transmitted to a motor and steering relay in the torpedo by an insulated cable. This cable has two cores and is paid out by the torpedo as it travels through the water just as a spider pays out his web. The cable is about half an inch in diameter and two miles long and the torpedo can be driven at about eighteen miles per hour with a current of thirty amperès and 1800 volts pressure.

Still another auxiliary weapon of defence is the dynamite gun, or rather, a pneumatic gun, that throws long projectiles carrying from 250 to 450 pounds of dynamite, to a distance of about two miles. The shells are arranged to explode soon after striking the water, by an ingenious battery that ignites the fuze as soon as the salt water enters it. This gun, which is known as the Zalinski Gun, is some sixty feet long and fifteen inches in caliber, the compressed air being suddenly admitted to it from the reservoirs at any desired pressure by a special form of valve that regulates the range. These guns are to be mounted in deep pits and fired at somewhat higher elevations than ordinary guns, but it has great accuracy within reasonable limits of range.

FIELD FORTIFICATIONS.

In field fortification an enormous quantity of work was done during our last war. Washington, Richmond, Nashville, Petersburg, Norfolk, Newberne, Plymouth, Vicksburg, and many other cities were elaborately fortified by field works which involved the handling of vast quantities of earth and, where the opposing lines were near together, ditches, abbatis, ground torpedoes, and wire entanglements were freely used. In some cases the same ground was fortified in succession by both armies, so that the total amount of work expended, in this way, would have built several hundred miles of railway. Around Richmond and Petersburg alone the development of field works was far greater than Wellington's celebrated lines at Torres Vedras. In all future wars when large armies are opposed to each other, it is probable that field works will play even a more important part than in the past. The great advantage of such works, since the introduction of the deadly breech loading rifles and machine guns, was shown at Plevna where the Russians were almost annihilated in attempting to capture the Turkish intrenchments.

SIEGES.

It is not proposed to go into historical, or other details of this branch of the subject, but to give in a condensed form some account of siege operations. According to the text books, the first thing to be done, if possible, in case of a regular siege, is to "invest" the fortress. This is done by surrounding it as quickly as possible with a continuous line of troops, who speedily intrench themselves and mount guns bearing outward on all lines of approach to the fortress, to prevent the enemy from sending in supplies or reinforcements. As this line must be at considerable distance from the fort it is usually quite long and so is its name, for it is called the line of "Circumvallation." Inside of this line is then established a similar line facing towards the fort to prevent sorties by the garrison. This line is called the line of "Countervallation," and should be as close to the fort as the range of its guns and the nature of the ground will permit. From this line the troops rush forward at night and open the trenches, beginning with what is called the first parallel, which should be so laid out as to envelop those parts of the fort which are to be made the special objects of attack. From this first parallel a number of zig-zag trenches are started towards the fort and at proper intervals other parallels, batteries and magazines are built; this method of approach being continued until the besieged fort is reached, or until such batteries can be brought to bear upon it as to breech the walls and allow the attacking troops to make an assault. During these operations of course many precautions must be observed, both by the attacking and defending force, to annoy each other and to prevent surprise, and the work is mostly carried on under cover of the earth thrown from the trenches. These operations were supposed to occupy under normal conditions, about forty-one days, or rather, nights, as most of the work is done after dark, at the end of which time the fort should be reduced to such a condition that its commander having exhausted all means of defence would be justified in considering terms of surrender.

The Theoretical Journal of the siege prescribes just what is to be done each day by both attack and defence up to the final catastrophe, and this somewhat discouraging outlook for the defenders was forcibly illustrated by the late Captain Derby, better known by the reading public as "John Phoenix" who, when a cadet, was called upon by Professor Mahan to explain how he would defend a fort, mounting a certain number of guns and garrisoned by a certain number of men, if besieged by an army of another assumed strength in men and guns, replied: "I would immediately evacuate the fort aud then besiege it and capture it again in forty-one days." Of course, the fallacy of this reasoning was in the fact that the besieging army is generally supposed to be four or five times as large as the garrison of the fort; the primary object of forts being to enable a small force to hold a position, at least for a time, against a much larger force of the enemy.

Sieges have changed with the development of engines of war, from the rude and muscular efforts of personal prowess like that described in Ivanhoe, where the Black Knight cuts his way through the barriers with his battle axe, to such sieges as those at Vicksburg, Petersburg and Plevna, where the individual counted for very little, and the results depended upon the combined efforts of large numbers of men and systematic siege operations. It should also be noticed that modern sieges are not necessarily hampered by the rules laid down in text books, but vary from them according to circumstances. For example, many sieges have been carried to successful issues without completely investing or surrounding the fortress. This was the case at Petersburg, where General Lee was entirely free to move out, or receive supplies and reinforcements up to the very last stages of the siege. In other cases, as at Fort Pulaski, Sumter and Macon, the breeching batteries were established at very much greater distances than ever before attempted, and the preliminary siege operations were very much abbreviated and some of them omitted altogether. This is not an argument against having well defined rules and principles, but it shows that the engineer must be prepared to cut loose from old rules and customs whenever the changed state of circumstances requires different treatment.

MILITARY BRIDGES.

In the movement of armies, especially on long marches in the enemy's country, one of the greatest difficulties to be overcome is the crossing of streams, and this is usually done by means of portable bridges. These may be built of light trestles with adjustable legs to suit the different depths, or of wooden or canvas boats supporting a light roadway wide enough for a single line of ordinary wagons or artillery carriages. The materials for these bridges, which are known as Ponton Bridges, are loaded upon wagons and accompany the army on its marches and when required for use the bridge is rapidly put together, piece by piece, in accordance with fixed rules, which constitute in fact a regular drill. The wooden boats are quite heavy and are used for heavy traffic, but for light work, as for example to accompany the rapid movements of the Cavalry, boats made of heavy canvas, stretched upon light wooden frames, that are put together on the spot, are used.

During Gen. Sherman's memorable Georgia Campaign and march to the Sea, over three miles of Ponton Bridges were built in crossing the numerous streams met with and nearly two miles of trestle bridges. In Gen. Grant's Wilderness Campaign the Engineers built not less than thirty-eight bridges between the Rappahannock and the James Rivers, these bridges aggregating over 6600 feet in length. Under favorable circumstances such bridges can be built at the rate of 200 to 300 feet per hour, and they can be taken up at a still more rapid rate. When there is no bridge train at hand the Engineer is obliged to use such improvised materials as he can get; buildings are torn down to get plank and trees are cut to make the frame. Sometimes single stringers will answer, but if a greater length of bridge is required it may be supported on piles or trestles, or in deep water on rafts of logs or casks. But the heavy traffic of armies, operating at some distance from their bases, must be transported by rail, and the building of railway bridges or rebuilding those destroyed by the enemy is an important duty of the Engineer. On the Potomac Creek in Virginia a trestle bridge 80 feet high and 400 feet long was built in nine working days, from timber out of the neighborhood. Another bridge across the Etowah River in Georgia was built in Gen Sherman's Campaign, and a similar bridge was also built over the Chattahoochee.

SURVEYS AND EXPLORATIONS.

For more than half a century before the building of the great Pacific Railways, Engineer Officers were engaged in making surveys and explorations in the great unknown country west of the Mississippi River and the final map of that country was literally covered with a net-work of trails made by them. Several of these officers lost their lives in such expeditions while others lived to become more famous as commanders during the great rebellion. Generals Kearney, J. E. Johnson, Pope, Warren, Fremont and Parke, and Colonels Long, Bache, Emory, Whipple, Woodruff and Simpson, Captains Warner, Stansbury, Gunnison and many other officers, generally in their younger days, contributed their quotas to the geographical knowledge of the country, and made possible the wonderful net-work of railways guarded by military posts that has followed their footsteps. Their reports fill twelve large quarto volumes.

BOUNDARY AND LAKE SURVEYS.

The astronomical location of the boundaries of the several states and territories, as well as of the United States, is a duty frequently required of the Engineer Officer, and such a survey between this country and Mexico is now in progress. The entire line of the 49th parallel of latitude from the Lake of the Woods to the Pacific Ocean, which forms our northern boundary, was located a few years ago by a joint commission of English and United States Engineers, and monuments were established at short intervals over its entire length.

A careful geodetic and hydrographic survey of the Great Northern Lakes, including every harbor upon them and the rivers connecting them, was carried on for many years and was finally completed some ten years ago. Maps and charts of these surveys are published from time to time for use of pilots navigating these waters.

Not only are the duties of the Military Engineer similar in many respects to those of the Civil Engineer, but there are many instances in which the duties of one branch of the profession have been performed by members of the other branch, quite as efficiently as though they had been performed by Engineers specially educated for the purpose. During the late Civil War there were many illustrations of this, all showing that an ingenious Engineer can readily adapt himself to circumstances entirely different from those to which he has been accustomed. A very good example of this occurred in the Red River Expedition of General Banks and Admiral Porter. In that memorable but disastrous campaign an army accompanied by a fleet of transports and light draft gun-boats, sometimes called "Tin Clads" because some parts of them were covered with boiler-plate to stop the bullets of the enemy, ascended the Red River in Louisiana; but the advance having been checked and a retreat commenced, it was found that the river had fallen to such a low state that the fleet was caught above the rapids near Alexandria, and it would in all probability have been a complete loss had it not been for the timely application of engineering skill by Lieut. Col. Joseph Bailey, a civil engineer from Wisconsin, who built a tempory dam across the river below the rapids and floated out the entire fleet. This dam was over 750 feet long and in connection with some auxiliary dams raised the water level some 6½ feet. It was built under many difficulties, but by the skill and ability of the engineer and the coöperation of the troops it was completed in ten days. Another case was at the siege of Petersburg, Va., where Lieut. Col. Pleasants, a Pennsylvania coal miner, ran a gallery from our lines, under the rebel battery, some 500 feet distant, and blew it entirely out of existence. The mine contained four tons of powder and produced a crater 200 feet by 50 feet and 25 feet deep, and was completed in one month. The sequel to this was to be an attack on the enemy's line through the gap made by the explosion, and such an attack properly followed up would doubtless have had a marked effect in shortening the duration of the war, but this attack was so badly managed that it utterly failed and caused a severe loss to our own Army. The mine itself, however, was a great success and produced a decided moral effect on both sides which lasted until the end of the war.

It may not be out of place to digress a moment to illustrate the moral effect of such a convulsion. Several weeks after this great mine explosion, the 18th Army Corps, to which I then belonged, was holding a line of works recently captured from the rebels, about six miles from Richmond, when one night the Colonel commanding Fort Harrison, a large field work forming a part of this line, came down to headquarters and reported that some old Pennsylvania coal miners in his command had heard mining going on under the fort. As the nearest part of the enemy's line was some 400 yards from the fort, I was quite certain that they could not have run a gallery that distance in the time that had elapsed since we occupied the work, but there was, of course, the possibility that the mine had been partly built beforehand so as to be ready in just such a case as had arisen, vis.: the capture of the fort by our troops. I therefore went with the Colonel up to the fort to listen for the mining operations, and got the men who claimed to have heard the subterraneous noises, down in the bottom of the ditch of the fort, which was some ten feet deep, and at the angles formed a fairly good listening gallery, but nothing unusual could be heard. I therefore made arrangements to sink a line of pits in the bottom of the ditch, something like ordinary wells; the bottoms of these pits to be finally connected by a horizontal gallery which would envelop the fort and enable up to hear the enemy and blow him up, before he could get under the fort. Although the commanding officer of that fort was as brave an officer as the war developed, he would not keep his men in the fort after dark, but withdrew them quietly to the flanks of the work where they would not only be safe from an explosion, but would be ready to fall upon the enemy in case he should blow up the fort and rush in to capture the line, as our troops had attempted to do at Petersburg. No explosion took place, however, and after our countermining work was completed, the garrison became reassured and remained in the fort at night as well as in day time. A few months later, when the enemy was driven from his lines, I went through his works to see whether any mining had been attempted and found that a gallery leading towards Fort Harrison had been carried quite a distance, but was still incomplete, and it is barely possible that the old miners were right, after all, in thinking that they could hear the sound of the pick, although the distance was almost too great to make this theory very probable.

Still another illustration of the way in which civil engineers can make themselves extremely useful in military operations was the wonderful system of military railways, or railways operated for military purposes, that formed complete lines of transportation for the armies and their enormous quantities of supplies and munitions, more especially those in the west and southwest. Construction trains were organized in the most complete style and when a piece of track, or a number of bridges were destroyed by the enemy, they would be rebuilt so rapidly that our trains would hardly seem to be delayed by it. The trains carried spare rails, ties, and bridges of various lengths ready to put up, and they also carried the necessary rolling stock and tools for destroying the roads and bridges of the enemy. So expert had this construction corps become that the enemy was ready to believe almost any statement in regard to it. General Sherman tells of an instance where it was proposed to blow up a tunnel, to check his "March to the Sea," when one of the men objected saying, it was of no use, for Sherman had a duplicate tunnel in his train.

Although this is not a sermon it may not be out of place to point out a few qualifications common to all engineers, for they all deal more or less with the same materials and forces and employ similar methods of investigation and construction. Wood, iron, steel, copper and stone and their compounds are the materials of the civil, mining, mechanical and electrical, as well as of the military engineers. They all deal with the forces of gravitation, cohesion, inertia and chemical affinity. They all require skill, intelligence, industry, confidence, accuracy, thoroughness, ingenuity and beyond all sound judgment. Wanting in any one of these qualifications an engineer is more or less disqualified for important work. It is said that a distinguished engineer was always afraid to cross his own bridges, although built in the most thorough and approved manner. He was deficient in confidence. Another engineer distinguished for his mathematical attainments built a bridge which promptly collapsed at the first opportunity.

On overhauling his computations he ejaculated somewhat forcibly, "That confounded minus sign! It should have been plus." He was deficient in sound judgment, or what is sometimes called "horse sense."

Another and more common defect in young engineers is a want of thoroughness. It is generally best to go to the bottom of a question at first and keep at it until it is thoroughly and fully completed. Confucius says, "If thou hast aught to do, first consider, second act, third let the soul resume her tranquility." Those who begin a great many things and never fully complete them, lose a great deal of valuable time, but do very little valuable work. The way to avoid this difficulty is to be cautious about beginning things, but when once started don't leave it until you are satisfied to leave it for good. There is an Arabian saying, "Never undertake *all* you can do, for he who undertakes *all* he can do will frequently undertake *more* than he can do."

Another common error is extravagance. On the plea that "the best is always the cheapest" and to be sure of a large factor of safety, or as the late Mr. Holley called it a "factor of ignorance," without much trouble to themselves, some engineers use more or better materials than the work requires and thus greatly increase the cost without any corresponding advantage. Almost any engineer can do almost anything in the way of engineering if not limited by the cost, but the man who knows just what materials to use and how to use them so that they will answer the purpose as to strength and durability, can save his own salary to his employer many times over by simply omitting unnecessary expense.

HEAT FROM ELECTRICITY.*

(*Concluded.*)

HEATING OF ISOLATED PLANTS.

Coming now to our third division, we introduce for the first time the cost of the generating and distributing tanks. A very little calculation served to show that, at the figures now quoted by manufacturers of electrical machinery, the interest on the first cost would be so great as to prohibit its use in any but extreme cases. It therefore seemed necessary to design all the electrical machinery required, and to make estimates upon it, in order that we might find what, allowing a fair profit, say of 20 to 25 per cent., would be the cost of such machinery. This was made all the more imperative by the advisability of using very large units as compared with those used in lighting and railroad work, both because of the large amounts of energy required and because, the source of power being necessarily water, small differences in efficiency with less than full load, would not be important. Having these matters in mind then, we designed a 1000 volt, 750 ampere dynamo, calling its capacity 1000 delivered H. P.

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*Selection from a thesis for the degree of M E., by George Ray Chamberlain and Francis Cary Caldwell, A.B., 1891.

The most favorable case, is evidently a factory supplied with an abundant water power, and in which, if steam heat is used, a special plant must be provided. Such a plant will be considered, requiring at times of maximum cold a dynamo of 500 H. P. If the dynamo could be located within the factory, so that any heat produced by it could be utilized, the efficiency would be 100 per cent.; still, to be on the safe side, we will consider the dynamo efficiency, namely, 90 per cent.; thus we have $746 \times \frac{500}{250}$ = say, 1500 amperes. The cost of wiring in this case, if we include in it the cost of stringing resistance wires or strips of iron across the tops of the rooms for radiation, is the only other element of cost apart from the dynamo and exciter. As this is a factor which it is quite impossible to make any general estimates upon, we shall assume the whole cost of this part as balanced by the cost of putting in an equivalent steam plant, and the cost of the steam mains; in so doing we shall unquestionably give the advantage to steam. Estimating the boiler cost as $1.15 per actual H. P., we have for 450 H. P. $520. The equivalent amount of the pipe for radiation may be obtained thus: we have to supply 500 × .90 = 458 H. P. equals 19,100 B. T. U. per minute. In Robert Briggs' "Steam Heating" (Van Nostrand Series) we find about five B. T. U. per sq. ft. of radiating surface given out. Hence we shall require about 3,800 sq. ft. With nominal 1 in. pipe, outside diameter 1.31 in., we have .343 sq. ft. per running foot, hence we shall require 11,070 feet, which at 5.5 cents per foot gives $610. Hence for the total cost of the steam plant, we have $1,200, say. Interest and depreciation on this, taken at 8 per cent., is $96.

Estimating the dynamo at $5 per H. P. because of its decreased size, and allowing this to include an exciter, we have $2,250, upon which interest and depreciation at 8 per cent. gives $180. We now have to consider a factor, which varies, not only with the situation, but also with the year considered; it is the ratio of the heat actually needed to that which the plant is capable of giving in the course of the year. To give exact estimates for any given case, the average temperature for a number of years would have to be known; but here we must simply take probable values. Let us assume zero as our minimum external temperature, 70 degrees as our normal internal temperature, and for an average 35 degrees during the seven months, October to April inclusive; this latter assumption is supported by a series of observations made at Albany for the weather service. From this it follows, assuming twelve hours running per day, that the amount of heat used would bear to the total capacity of the plant the ratio, $\frac{7}{12} \times \frac{1}{2} \times \frac{1}{2} = .146$. Hence, since the total capacity, as shown above, equals 19,100 B. T. U. per minute, equals 10,040,000,000 B. T. U. per year. Take one million B. T. U. as a unit and we have the total capacity 10,040 units, and the actual production 1,470 units per year. The interest per unit then for the two methods, leaving out the cost of wiring and wire on one side, and of piping and mains on the other, gives for steam $.065, and for electricity $.125. To this must be added, in the case of the steam, the wages of a fireman for seven months, while the dynamo should require no further attendance than could be given by some employé of the establishment. Allowing $2 per day, the wages will be $350 for the seven months, which is equivalent to $.24 per unit, making a total of $.205. Now with the value of water power of $1 per H. P. per year delivered at the dynamo, we have its cost per unit equal to $500 divided by 1,470 equals $.34, and for any multiple of $1 the corresponding multiple of this. Similarly for coal at $1 per ton, and supposing the boilers to give 10,000 B. T. U. per pound of coal, or 100 pounds coal per unit, the cost of coal per unit is therefore five cents and the multiples of $1, multiples of five cents.

The equations of the two lines representing the variation of the cost of the unit with the cost per H. P. of power and with the cost per ton of coal are, therefore,

$$H = .34\,p + .125$$
$$H = .05\,c + .305$$

where H is the cost of a unit of heat in dollars, p the cost per H. P. of power, and c the cost per ton of coal.

COST FOR ONE MILLION BRITISH THERMAL UNITS BY STEAM AND BY ELECTRICITY, 12 HOURS PER DAY.

Steam Heating.		Electrical Heating from Water Power.	
Cost of 1,000,000 B. T. U.	Price of Coal Per Ton.	Cost of 1,000,000 B. T. U.	Price of H. P. Per Annum.
$0.355	$ 1.00	$0.465	$ 1.00
.405	2.00	.805	2.00
.455	3.00	1.17	3.00
.501	4.00	1.50	4.00
.555	5.00	1.86	5.00
.601	6.00	2.20	6.00
.655	7.00	2.56	7.00
.705	8.00	2.90	8.00
.755	9.00	3.22	9.00
.805	10 00	3.57	10.00
1.055	15.00	5.42	15.00

From these equations it appears that, granting the above assumptions, the use of electricity for heating such a plant in competition with steam cannot be possible except in most extraordinary cases of cheap power and dear coal. Thus with coal at $15 per ton, a most extravagant price for use in such a boiler, water power to compete could not be above $2.70 per H. P. per year, a very low figure, although it should be remembered that the greatest power for heating will be required before starting the mills in the morning and that all the power will be required at the season when the water supply is large and can easily be spared. The same electrical plant also can, without interfering with its usefulness for heating, be used by the addition of proper transformers for lighting and welding.

Consider also the case still more favorable to electricity, namely, when the mills run all night. Our factor is now doubled and becomes .292. The actual production of heat is then 2,935 units, the interest per unit, for steam $.0325, for electricity $.0625. Fireman's wages will be doubled and equal $.48, making a total constant for steam $.5125. The cost per H. P. may be halved, which makes 17 cents, while the cost per ton of coal will remain the same. Hence our equations become

$$H = .17\,p + .0625$$
$$H = .05\,c + .5125$$

This brings the matter very much further within the limits of possibility, though still hardly within those of probability ; thus with coal at $5 per ton, $4 could be paid per H. P. for power. If now during the five months when the plant was not in use for heating, the extra power could be used for any purpose. either electrical or otherwise, even if it no more than paid for itself, the cost of electric heat would be nearly halved, thus bringing it quite within the range of practicability for some cases.

The climate, as being warmer or colder, would give preference to the latter for electrical heating; for although the plant for the lower temperature would have to be larger, the cost of water power, which forms the major part of the expense, would be about the same, and otherwise the efficiency of the plant, supposing no use for it during the summer months, varies as the number of months per year during which it runs. Another condition which would have much more influence, would be the degree of uniformity of the temperature. Thus a locality where a minimum temperature was not very much below the average, would favor electric heating much more than the case taken where it was 35 degrees below. It may be well to note that by "minimum temperature" is not meant the lowest temperature reached during the winter, but the lowest at which the thermometer is likely to stand for many hours at a time.

HEATING FROM A CENTRAL STATION.

In taking up the fourth head, we have to add to our previous considerations, those of a housing for the plant and its care, also of the transmission of the energy and its proper dispersion by suitable radiators. Also the steam side of the account is modified by the increased cost of boiler per horse power, the much increased cost of radiating surface, the superior quality of fuel necessary, the decreased efficiency, and the omission of the factor of attendance.

First, as to transmission, we shall use as high a potential on the line as practicable, which seems to be about 5,000 volts; to obtain this we shall use a large converter in the station, transforming the product of the generators from 1,000 to 5,000 volts, the details of the transformer being given in the thesis.

By substitution in the above equations, and making a special estimate of the cost of insulation, the following results are deduced in the thesis:

Distance, one-half mile; receiving, 1,000 H. P.; delivering, 855 H. P.

Cost of H. P. per Year.	Cost of One-half Mile of Line.	Size of Wire B. & S. Gauge.
$ 4 00	$ 886 00	00
6 00	1,038 00	000
10 00	1,202 00	0000
14 00	1,616 00	2(00)
18 00	1,767 00	

Cost of Line, will consist of cost of copper and of the poles and erection of the line, the latter element remaining nearly constant.

Poles will cost, if of wood, in place, from $5 to $8, and should be placed at distances not exceeding 125 feet.

The amount of copper can not be determined unless the current is known, and its cost will vary inversely as that of the generator.

Using Thompson's rule, that the interest on the capital outlay for the line should equal the annual cost of the energy wasted, and distinguishing the variable quantity, we have the following equations:

$R = l r \div m.$

Energy wasted $= c l R \div m.$

Weight of line $= w l m.$

Annual cost of energy $= q c^2 l r \div m.$

Interest on cost of line $= p k w l m.$

Hence for minimum expense

$$p k w l m = q c^2 l r \div m$$

$$m^2 = q c^2 r \div p k w.$$

In which $r =$ resistance of a mil-foot of copper (108 ohms), $l =$ length of line, $c =$ current in amperes, $m =$ circular mils, $k =$ cost of copper per pound, $q =$ annual cost of 1 watt, $w = .000,003,021$ lbs. (weight of mil-ft. of Cu.), $R =$ total resistance of line, $p =$ per cent. for interest and depreciation $= 8\%$, M is independent of the distance.

HOW CLOSELY CAN WE SUBDIVIDE DECIMALLY BY THE EYE?

BY PROF. W. F. DURAND.

The students in Naval Architecture having recently had much occasion to measure dimensions from drawings and tracings, it seemed an interesting experiment to attempt to determine the approximate degree of accuracy with which such dimensions could be read off by means of a rule subdivided into tenths of inches, the remaining subdivisions being estimated decimally. To this end a series of ten distances was laid down at hazard. Ten members of the class measured these distances in the manner indicated. The distances were then accurately measured and the successive errors found. The mean error of the class for the ten observations was .0033″. In finding this mean error, it will be observed that it is the arithmetical sum of all the errors divided by the number of observations. The algebraic sum cannot be used in this case, because positive and negative errors do not tend to balance each other. Each measurement is a single separate observation ; and an error, whether positive or negative, is by that amount a departure from the exact value, and under such circumstances the mean error will be the mean of such departures.

The maximum mean error of one individual was .005″. The minimum mean error of one individual was .0019″. The maximum single error was .015″, and this occurred but once in the one hundred observations. The minimum single error was zero, and this occurred thirty-seven times in the one hundred observations

Passing now to the distribution of errors as to positive or negative, it was found that of the sixty-three errors, forty-four were positive ; that is, the estimated distance was greater that the actual. This gives 70 per cent. of the errors as positive. With two individuals all of the errors were positive, respectively seven and eight in number out of the ten observations. With one individual all of the errors were negative, six in number.

Turning now to the actual values of the distances, half of them were even hundredths ; that is, even tenths of the distance to be subdivided by the eye. As would be expected, the errors on these observations were much less than on the others.

The mean error on these exact hundredths was .002. The maximum mean error of one individual was .005, occurring in one case only, while the minimum mean was zero, occurring in three cases. The maximum single error on these observations was .01, occurring four times out of the fifty, while the error zero occurred thirty-four times out of the fifty. That is, 68 per cent. of the observations on exact hundredths were exactly correct, and nearly all of the remaining errors were .005″ arising from an attempt to subdivide the hundredth into halves. If the observers had been content with the estimation to whole hundredths, it is probable that of the errors .005″, about one-half would have been zero, and the remainder .01″ This would not have effected the mean error essentially, but it would have raised the number of exact observations to about 80 per cent.

Turning now to the individual distances, we find that the estimations of .05″ and .02″ or .08″ were effected with the greatest accuracy. The first, involving simply a bisection, is as we should expect; whether the second is more than accidental, further experiment alone can determine. On each of these one individual only made an error, in one case .01 and in the other .005. The former was on the bisection of the tenth, and it is so large as to suggest the probability of its being due to accidental carelessness in estimating.

On the estimation of 09″ or .01″, four observers were in error from .005″ to .008″. On the estimation of .07″, of which there were two instances, five observers in each case were in error, and four of these were the same individuals in both cases.

Thus far the errors have all been stated in absolute magnitude. Stating them now with reference to the size of the distance to be subdivided, we may sum up as follows: The mean error of all observations was 3.3 per cent., the minimum error of one individual was 1.9 per cent., the maximum error of one individual was 4.5 per cent., and similarly for other proportional amounts. It therefore appears that the errors committed by estimation under the circumstances described are surprisingly small, and that with a scale subdivided to tenths inches, even hundredths may be read with almost absolute certainty and with far less strain on the eyes than is occasioned by the employment of a finer scale.

It is certain that the accuracy with which a distance can be decimally subdivided depends on the distance. The experiments thus described were all on one-tenth inch as a base. Other experiments on larger distances are in progress to determine about what length may be most readily and accurately so subdivided. A further point to be elucidated by such experiments is as to the relative accuracy with which the various subdivisions may be effected. These results may appear at some later time.

THE CRUSHING RESISTANCE OF BRICKS.

The Department of Experimental Engineering recently received from an Ithaca manufacturer four samples of brick to be tested. All the brick were tested entire and on edge, as they would be used for the purpose of paving. The sides were dressed to parallel planes on an emery wheel, so that the bearing should be uniform over every part. A single layer of thick paper was placed between the surfaces of the brick and the testing machine.

The following shows the results of the test in tabular form :

RESULTS OF TESTS.

Name of Brick.	No. 1.	No. 2.	No. 3.	No. 4.
Weight of brick, lbs.	4.86	5.14	5.1	5.00
Dimensions	$7\frac{3}{4}$x$3\frac{5}{8}$x$2\frac{3}{16}$	8x$3\frac{7}{8}$x$2\frac{5}{16}$	8x4x$2\frac{5}{16}$	$7\frac{3}{4}$x$3\frac{3}{4}$x$2\frac{5}{16}$ inches
Cubic contents . . .	61.35	70.7	74.0	67.20 cubic in.
Area strained . . .	16.95	18.5	18.5	17.92 sq. in.
Height of column . .	$3\frac{5}{8}$	$3\frac{7}{8}$	4	$3\frac{1}{4}$ inches.
Total Stress.				
First crack	208000	84000	56000	48000 pounds.
Splinters fly	250000		133000	108000 "
Crushed	254000	172000	180000	141200 "
Stress per sq. in.				
First crack	12230	4580	3508	2600 "
Splinters fly	14800		8362	6000 "
Crushed	14990	9300	10909	7880 "
Color of brick . . .	Light cream.	Light cream.	Light cream.	Red.
	Homogen. columnar.	Black vitrified.	Homogeneous.	Homogeneous.
Fracture.				
Position first fracture	One corner.	Central.	Central.	At one end.
Direction of fracture	Vertical.	Diagonal.	Vertical.	Vertical.
Kind of brick	Repressed.	Common.	Common.	Common—top soil.
Specific gravity . . .	2.18	2.01	1.91	2.07
Wt. per cubic foot .	136.9	125.6	118.8	129.0 pounds.

The repressed brick exhibits the greatest crushing strength of any brick on record ; it is also superior in strength to sandstone, and fully four-fifths as strong as granite. The tests of stone are usually made on cubes one or two inches on each edge, and such tests show a greater strength per square inch than would be the case if the form of the block was like that of the brick tested ; so if the proper allowance for form should be made, there is little doubt but that the crushing strength of brick No. 1 would compare favorably with the strongest granite. The best results from ordinary pressed brick usually show a strength from 6,000 to 10,000 pounds per square inch, so that the other bricks tested, considering the quality and method of manufacture, show an extraordinary strength. No test could be made for wearing qualities, but the brick exhibit, so far as can be determined by striking them with a hammer, sufficient toughness to make them a superior article of paving brick.

Dr. R. H. Thurston made for Mr. C. H. Haswell a thorough test of a specimen of brick from Newburyport, Mass., in 1876, and the following is quoted from his report: "In consequence of the very great resistance of your manufacture that you forward me, it was impracticable to test them, except under the disadvantage of dressing them down to cubes of but one inch, and thereby removing their outside surface; and notwithstanding this they gave the unprecedented result of a mean resistance of 9,353 pounds per square inch. Their specific gravity is 2.433."

THE COURSE IN MARINE ENGINEERING.

FALL TERM.

The following is a brief abstract of the work completed during the past term in the course in Marine Engineering:

The course of lectures treated of the following topics: Approximate Methods of Integration; Displacement; Center of Buoyancy; Center of Gravity; Metacenter; Stability; Strain on Ships as a whole, and calculation of the Equivalent Girder; Oscillations of Ships; Wave Motion; Resistance; Fronde's Daw of Comparison; Powering Ships; Propulsion, more especially by the Screw Propeller; Design of Paddle-wheels and Screws; Various forms of Screws; Drawing of Screws; Subdivision and distribution of I. H. P.

For application of the principles enunciated in the lectures, a set of actual lines was given each student, upon which all his computations were based. The following were made by each one: Displacement sheet showing center of buoyancy fore and aft and vertically, metacenter, displacement curve, and tons per inch curve, with accompanying computations; Computation of wetted surface by "Kirk's Model;" Computation of I. H. P. from four formulas involving midship section, displacement, wetted surface, and augmented surface, with discussion of the constants involved; Laying down a speed and I. H. P. curve; Design and drawing of a screw propeller suited to drive the boat at a given speed; Distribution of the I. H. P. The above work was taken by eleven students. In addition a few put in extra time in stability computations, and engine and boiler design, according to their personal choice.

A PALPABLE HIT.

The following correspondence, which was held between a senior of a prominent institution of learning and a very practical engineer of wide experience, has been placed at our disposal and thinking it might be of considerable value to some seniors, it is published herewith :

COLLEGEVILLE, Jan. 1, 1889.

——— ICE MACHINE CO., FACTORYVILLE :

Gentlemen—I am a member of the senior class of the ——— and together with a classmate intend to take the subject of refrigeration and refrigerating machinery for a thesis. We expect to go rather deep into the subject and will probably make quite a number of experiments, and probably will design a complete plant for the manufacture of ice, making estimates of cost of buildings, machinery, etc. At present I may say that we know little or nothing about the practical side of the subject, but we have about two months' allotted time to work upon it, besides what leisure time outside of this that we can devote to it, and if you have any data or information at your disposal that would be of interest to us, we would be very thankful indeed for any kindness you might show us. Would like to have your catalogue, and if you have a blue print of some plant that you have erected that you could send with some idea of its cost, it would be a great help to us and I assure you appreciated very much. I suppose that a sixty ton plant would be about the size that we would want to get up.

Thanking you very much for your attention, and hoping to hear from you in the near future, I am,

Very respectfully,

Signed, ———

FACTORYVILLE, Jan. 11, 1889.

———, COLLEGEVILLE :

Dear Sir—Your favor of the 1st inst. disclosing your project for paralyzing your Professor with the thesis in which you "intend to go deep into the theory of the subject," "design a complete plant," "estimate upon the cost of same," "cost of manufacturing the ice," etc., together with the design and cost of buildings adapted to receive the machinery, received. We congratulate you upon your conceit or ambition in this direction, we do not know which it is, and should judge that in order to be able to cope successfully with the subject that you have had large previous experience and are rather an old student, possibly forty or fifty years of age. We hardly believe that it is as you say, "that you know little or nothing about the practical side of the question."

We are rather afraid to interfere with your project, and will not supply you with the drawings or literature on the subject, because you may evolve something that would be worth giving to the world. We would have suspicion otherwise that you would be to a very large extent governed by what we, or others in the business, might give you. If you succeed in demonstrating your capabilities in the lines in which you have indicated, and are so versatile that you can go with one bound from the lowest depth of practice to the highest plane of theory, consider from a commercial point of view all the questions involved successfully, we wish to make a bargain with you, that as soon as you graduate you take the first train for Factoryville. We are looking for a man that will cover the ground you have outlined.

Yours truly,

Signed, ———, M. E.

N. B.—We have relented, and send you a copy of our catalogue and a 50 ton ice plant drawing. Let us hear from you again. Let us have a copy of your thesis and see what a mess you make of it. Don't you think that too much is too little for the undertaking?

THE ASSISTANT PROFESSOR OF NAVAL ARCHITECTURE.

The second appointment in the school of Marine Engineering and Naval Architecture has recently been made. The incumbent is Mr. Geo. R. McDermott, who takes the position of Assistant Professor of Naval Architecture. Professor McDermott studied first for the profession of house or civil architecture, but becoming somewhat dissatisfied with the work, turned his attention to naval architecture and ship-building. In 1879 he entered the drawing offices connected with the ship yard of J. and G. Thompson, on the Clyde. He remained in this work for three years and was then made chief of the scientific staff in the same establishment. This place he held for seven years, when he accepted a position with the Southampton Naval Works, where he held the position of naval architect to the yard. This establishment becoming financially involved, Professor McDermott accepted the position in Cornell University which he now holds. During his experience in these ship yards, Professor McDermott has taken part in the design of some seventy-five ships. Among the more important of these may be mentioned the Atlantic liners Servia, Aurania, America, City of New York and City of Paris, the Spanish naval cruiser Reina Regente, the English 14,000 ton battle ship Ramilies, and the torpedo boats Wiborg and El Destructor. Professor McDermott's work here will include everything relating to practical ship design, drawing, and construction, a line of work for which his previous experience has rendered him exceptionally well qualified.

STRENGTH OF "EXPANDED" CONNECTIONS.

It is often asked: What is the strength of a connection between a tube and its tube-plate, as made by the familiar process of "expanding" as by a Dudgeon or other good form of "expander." The following report gives this information in a very satisfactory manner, as furnished by the administration of the *Conservatoire des Arts et Métiers* at Paris, recently. The occasion was the test of a set of Babcock & Wilcox tubes expanded into a sheet as illustrated by their connection, ordinarily, of their mid-drum with the system of circulating tubes. An accident had occurred at a French establishment about starting up one of these boilers, in consequence of the neglect of the man entrusted with its erection to see this joint properly made, and this accident was made the text for a sharp attack upon the system by a distinguished engineer engaged in competing work. The builders, therefore, proposed to ascertain what is really the strength of this connection where the work is properly attended to and well performed, claiming that they were no more responsible for bad workmanship by others, either in construction or erection, than would be the designer of a standard tubular boiler for the reckless use of the drift-pin or for a scored seam in its construction. In the case under consideration, they had no control of the work causing the accident.

(*Translation.*)

CONSERVATOIRE NATIONALE DES ARTS ET MÉTIERS.

Report on tests made on the resistance of the jointing of three steel tubes, submitted by the Babcock & Wilcox Co.

The manager of the Babcock & Wilcox Co. of 15 Rue de la Chaussée d' Antin submitted to the Conservatoire des Arts et Métiers three steel tubes, to have them tested with regard to their resistance at the jointing. The three tubes were of 0 m., 100 mm. outside diameter and 0 m., 0035 mm. thickness, the first tube 1 m., 650 mm. long, and the other two 1 m., 280 mm. total length, all lam welded and having their ends expanded into cast iron double flanges as shown in the annexed sketch, arranged to receive in one a screw plug to release the air, and in the other a brass connecting piece, made according to a template by the Conservatoire, for connecting up to the delivery pipe of a pressure pump. With the first tube, which was brought all expanded, the pressure, which was measured by a Bourdon's pressure gauge, progressively reached 150 kilogs. per sq. centimetre, without in the least affecting the solidity of the joints; it was only under a pressure of 152 kilogrammes that the tube pulled out of one of the flanges. The two other tubes were expanded at the Conservatoire by one application of Dudgeon's tube expander. The first of these tubes, expanded from outside, burst without change in the expanding, at a pressure of 242 kilogs. per sq. centimetre. In the second tube the expanding was done from the inside, and at 90. 52 and 72 kilogs. leaks occurred at both ends, and after each of the above pressures the expander was applied, still from the inside, and the pressure afterwards reached 265 kilogs. per sq. centimetre without bursting the tube, affecting its joints, or causing fresh leakages.

These various tests, at the greater part of which was present Mr. Thomine, engineer of the Babcock & Wilcox Co., were made in the presence of Mr. Dalle, clerk of the administration of the Conservatoire.

Paris, February 5, 1891.

Report by the engineer of the Conservatoire national des arts et métiers.

[Signed] LEON MASSON.

Approved by the Director of the Conservatoire des arts et métiers.

[Signed] LAUSSEDAT.

ANOTHER CORNELL MAN HEARD FROM.

ELECTRIC LIGHTING FOR CABLE CARS.

For the past month or two experiments have been made on the Butlet street branch of the Citizens' Traction line in lighting their cable cars by electricity. These experiments came to a successful conclusion Saturday night and last night the officers of the road witnessed its working. This method is the invention of George Francis Myers, of this city. Cable lines in Pittsburg have experienced considerable difficulty and inconvenience with the smoky oil lamps, and it is understood they are all anxious to adopt any system doing away with the trouble. The one car illuminated by the above method last night by seven incandescent lamps was as bright as day, and a newspaper could be comfortably read at the farther corner of the car. —*Pittsburgh Dispatch, Jan. 6, '92.*

THE CRANK.

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LORD THOMSON.

Sir. Wm. Thomson, now approaching his limit of threescore and ten years, (born June, 1824) has just been "raised" to the peerage by the British government, as a New Year's tribute to his, by them, tardily discovered genius. After forty-five years of such extraordinary and fruitful labor as have placed him far above any contemporary in science, and having become acknowledged as the head of his profession throughout the world, in both pure and applied physical science, having taken his place as the leading author, the most expert mathematical physicist, the greatest inventor, the most helpful man of science of the world in the department of the physical sciences, and, after having been tendered every distinction that the rest of the world could offer him, he has at last been discovered by his own government. Even now, as remarked by Mr. Smalley, "Sir William Thomson's eminence in the scientific world might not have marked him out for the peculiar distinction of the peerage had not his science borne practical fruits. His services to telegraphy and to navigation cannot be too highly rewarded. To enter the House of Lords seems, however, an odd ambition for such a man, who is just the man of science to receive this kind of recognition from his sovereign."

Our distinguished friend is to be congratulated, however, that *at last*, the prophet is not without honor even in his own country. This will give him another line or two in "Men and Women of the Time," that somewhat uncertain record of many great and some little men.

A NEW FIELD FOR SIBLEY GRADUATES.

The annual report of the Secretary of the Navy, just published, contains much that is of interest to students in Sibley College, and especially to those taking work in marine engineering and naval architecture. The new protected cruisers, Nos. 12 and 13, are well under way and represent the highest art of the marine engineer. They will have a maximum speed of 21 knots an hour at sea, 22 in smooth water, and, at ten knots, can steam ten thousand miles without stopping for coal. They have three screws each, are lightly armored, and carry 8, 6, and 4-inch guns, and an outfit of torpedoes. Thirteen new vessels have been built since March, 1889. Some of these ships have 10 and 12-inch guns, and are protected by armor, in some cases 12 inches in thickness. Most of the ships now under construction will be finished in 1892, some in 1893 and the rest in 1894. There are of these twenty-three in all, carrying about 350 guns, and among them many from 6 to 10-inch, and some as large as 12 and 13-inch. The new guns are usually of 35 and 40 calibres length, and are found to have very great range and penetrating power.

The new smokeless powder, invented by Professor C. E. Munroe, U. S. N., formerly professor of chemistry at the Naval Academy and now at the Naval War College at Newport, R. I., is considered the best yet discovered by the Navy Department, and will probably be adopted for even heavy guns. It has already been used in the 6-inch rifle. It gives two hundred feet higher velocity than the old powders, has no volatile constituents, is unaffected by heat and even by boiling water, and gives sustained pressure.

The Carpenter Steel Co. are making a projectile which possesses infinite superiority in armor-piercing power over the old Pallister and other forms, and the nickel Harveyed plate is also superior in resisting power to anything hitherto known. The construction of torpedo-boats is recommended, and in considerable numbers, as the most effective and cheapest of all known means of defense at home. A contract for one of these boats has recently been taken by a firm in Iowa, at Dubuque, on the upper Mississippi, a fact which is very significant of the elements which, in this country, add to our safety in time of war.

Perhaps the most interesting part of the report of General Tracy is that which relates to the *personnel* of the Engineer Corps. He says: "It is false economy to put in our new vessels all that is most advanced in high-pressure machinery and the multitude of engines and devices by which steam and mechanical appliances are made to do the work of man, and then provide an insufficient number of officers to control them." . . . . . The Secretary then commends the plan of the Engineer in-Chief of the Navy, Commodore Melville, proposing a large increase in the now restricted number of engineer officers, and a better and more strictly professional training. It is proposed to take, in addition to the regular graduates of the Naval Academy, in the Engineer courses, a certain number each year from among the graduates of the better class of engineering schools of the country at large, and, giving them a year or two of special instruction and practice, commission them in the regular corps of Naval Engineers. This plan has been before Congress some two years, now, in the form of what is known as "The Butler Bill," and its passage would prove not only of incalculable value to the navy and to the country, but of great advantage to young men who, with every requisite of skill, ability, taste, character, and education, are now completely debarred from such a privilege, and the country loses their services, although actually in serious difficulty and in great need of just such men.

CRANK SHAFTS.

—Several seniors have already a good start on the experimental work for their theses.

—Mr. L. F. Chesebrough writes from Berkeley, Cal., that he likes his new position very much and that the climate is simply delightful.

—About twenty-five students have registered for Prof. Carpenter's course in Consulting Engineering, and the work promises to be very instructive.

—Mr. James McNamara, instructor in the machine shop, has resigned. He will leave this week for Brooklyn, where he will do some experimental work.

—A torn driving belt in the dynamo room caused quite a commotion a few days ago. There was a number of workmen in the room at the time of the accident and they proved themselves to be remarkable sprinters.

—The new triple expansion Reynolds-Corliss engine for experimental purposes, has been lined up and calked. M. N. MacLaren, '91, who is with the E. P. Allis Co., has been sent here to assist in the erection of the engine.

—Since the meeting of the committee late last term, nothing has been done toward securing a suitable emblem to be worn by Sibley graduates, and it is quite possible that in the absence of greater interest the question will be dropped for the present.

—The Director of Sibley College is frequently in receipt of applications for men to do engineering work in various capacities and often, also, to teach. Alumni having had some experience and desirous to change should inform him of that desire and state what work they prefer.

—Part Two of Dr. Thurston's Manual of the Steam Engine was issued January 2. The volume will be noticed more fully in the next issue of THE CRANK. Part One has already been adopted in this country in various Schools of Engineering, and has met with a flattering reception abroad.

—The University of Dublin, celebrating its tercentenary in July next, invites the Faculties of the principal colleges throughout the world to participate, among these, as a matter of course, including Cornell. Dr. Thurston has also received an invitation directly from the University of Dublin, and may arrange to be present on what will probably prove to be a most interesting occasion.

—The Marine Engineering Department has received from the Quintard Iron Works, four photographs showing the engines and machinery of the gun boats, Bennington and Concord, and large blue prints of the Bennington and Maine. A series of about one hundred and twenty drawings, showing plans and details of the engines of cruisers Newark and Raleigh, have also been received from the Navy Department.

—The New York Air Brake Company has presented to Sibley College one of their duplex air pumps. This pump, which is used in connection with the air brakes manufactured by this company, has some novel features and they claim for it a very great efficiency. A full brake equipment will probably be added to the gift as soon as the firm can get even with their orders. This apparatus will be highly appreciated.

—The new apparatus for testing indicators at the New York navy-yard is said to be the most perfect arrangement for the purpose ever constructed. Indicators are tested by direct steam pressure, measured by the mercury column, to which every possible correction is applied. The indicator is attached, steam pressure adjusted, and then a touch of an electric button presses the pencil against the paper and revolves the drum.

—The December issue of *Cassier's Magazine* begins its series of articles on "Technical Schools of America" with a description, by Professor Carpenter, of the Sibley College Laboratories. It gives a careful statement of the methods of instruction and the work done in the shops, and the electrical and mechanical laboratories for investigation and scientific research. There is a list of the more important apparatus in order to show the facilities for instruction in experimental engineering. The article is well illustrated and gives an excellent idea of the laboratory work in Sibley College.

—The President of the Commission appointed to erect a monument to the late and distinguished engineer, Mon. G. A. Hirn, of Colmar, Alsace, in acknowledgement of his extraordinary services in the development of the theory and the experimental philosophy of the steam engine, notifies Dr. Thurston that he has been tendered honorary membership in that commission. The tender has been accepted. It is hoped that it may be possible to secure a very substantial contribution to this great work of commemmoration of one of the greatest members of the profession of engineering, through American members from the profession in this country.

—A young graduate of Cornell, in the Sibley College course, writes: "I think, take it all in all, the street railway business is about as full of 'cussedness' as any you can find. 'Eternal vigilance is the price of safety,' is a saying which is exemplified in this as in few other occupations. There is an infinite number of ways how not to do it, which strange to say, are often followed in preference to the right way, and with the inevitable result:—Trouble with a large T. And there are more uneducated 'practical' bigots, playing with it at other people's expense, than in most industries. I find that men who brag of being 'practical' are not trustworthy, not to say difficult to deal with. I speak with feeling, as I have had some pretty hard knocks due to men of this description."

PERSONALS.

'88.

C. H. Glasser is with the Rand Drill Co., North Terrytown, N. Y.

H. N. Brooks is with the Thompson–Houston Company, at Lynn, Mass.

I. P. Disney and H. W. Fisher are with the Standard Underground Cable Co., at Pittsburgh, Pa.

F. R. Jones has charge of the Department of Mechanical Engineering at the University of Tennessee.

I. J. Macomber, who is with the Edison Co., at Watertown, was in Ithaca recently to see his son and heir.

Wm. A. Mosscrop is building an electric railroad at Tonawanda for Woodbridge and Turner (P. G. '86).

'89.

H. T. Brutt is in the New York Central shops, at Buffalo, N. Y.

O. M. Mowatt is with the Camden Iron Works, at Camden, N. J.

W. H. Baldwin is with the firm Ryan and McDonald, Baltimore, Md.

C. L. Cornell is with the Western Engineering Company, at Kearney, Neb.

'90.

F. C. Gasche is with the Illinois Steel Co., Chicago, Ill.

W. D. Mount is instructor in Physics at Brown University.

H. B. Prather is with the Buffalo Forge Company, at Buffalo, N. Y.

S. J. Larned is with the Long Distance Telephone Co., New York City.

P. K. Browd and A. R. McFarland are with the Solvay Process Company, at Syracuse, N. Y.

J. E. Greenawalt is with the Los Angeles Consolidated Electric Railway Co., at Los Angeles, Cal.

C. P. Miller is in the Draughting Department of the Lehigh Valley Railroad Co., at South Easton, Pa.

L. L. Smith is in the Mechanical Laboratory Department of the C. B. and Q. Railroad Co., at Aurora, Ill.

I. B. Smith is professor of Physics, Chemistry and Draughting at the Poughkeepsie Military Institute, at Poughkeepsie, N. Y.

CURRENT EVENTS.

Junior Ball, Jan. 29.

Glee Club Concert, Jan. 28.

Sophomore Cotillion, Jan. 27.

Founder's Day, Jan. 11, was a University holiday.

Delta Gamma gave a very pleasant reception at Sage, Jan. 15.

Professor G. C. Caldwell has been elected President of the American Chemical Society.

Candidates for the baseball team are practicing in the batting-cage in the Gymnasium annex.

The first number of Cornell's *Philosophical Review*, of which Professor Schurman is the editor, has appeared.

Instructor Studley has resigned, in order to accept a professorship in the Mathematical department at Wabash College.

Hon. Daniel H. Chamberlain has just completed a course of eight lectures on Constitutional Law, before the School of Law.

University of Michigan is scheduled to play a return game with Cornell at Percy Field on June 4. Cornell will play U. of M. at Detroit on May 7.

The C. U. C. A. has arranged a series of practical sermons to be given at Barnes Hall every Sunday evening during the term by prominent lecturers.

About twelve candidates are training for the 'Varsity crew, and a large number for the Freshman crew. The Freshmen have appointed a committee to solicit subscriptions to support their crew.

Mr. W. L. B. Jenney, of Chicago, delivered a lecture on "The Erection of Tall Steel Buildings on a Compressible Soil," in the Chemical lecture room, Friday evening, Jan. 15. The lecture was exceedingly interesting and was illustrated with lantern slides.

Professors J. Laurence Laughlin and William Gardner Hale have resigned from the Cornell Faculty, in order to accept positions as heads, respectively, of the Economic and Latin departments at Chicago University, where they will receive salaries of $7,000 per year each.

The water wheels of the new power system were shipped with all parts connected, so that in order to get them in place it was necessary to arrange very strong lifting tackle to lower them into the gorge. This operation, because of the lack of appliances for handling heavy weights, has proved very difficult and expensive, although the work has been accomplished without an accident.

THE CRANK

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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

CENTRIFUGAL FORCE AND RESULTING PHENOMENA.*

BY CHARLES E. EMERY, PH.D.

The comparative frequency of accidents to the fly wheels of steam engines during recent years has impressed the speaker with the desirability of an investigation of the general subject of centrifugal force, particularly the limitations which it imposes on the design of pulleys, fly wheels and other machinery, and the influence it will have in the near future on the speed of railway trains. It is proposed to illustrate the destructive effects due to centrifugal force by photographic representations of machinery and buildings injured in this way, and finally to state in general terms some features developed during recent litigation on the subject, which it is thought will be of interest to students of mechanical and electrical engineering.

The greater frequency of fly wheel accidents of late years can in part be traced to the comparatively high speeds at which engines are now being operated, but more especially to the higher strains on material now found desirable under the spur of competition to produce increased work in engines of a given size by the use of higher steam pressures. It does not appear that fly wheels of customary construction should be unsafe at the comparatively high speeds now in common use, if proper materials were always used in construction. The weight of evidence is, that the factor of safety of fly wheels operated at the low speeds formerly in vogue was so high that fly wheel disruptions were very infrequent, and that therefore no special care was taken to secure superior designs, materials and workmanship. It is a curious fact, also, that all the hand books, as well as most of the text books the writer has consulted, either fail to point out the manner in which the formula for centrifugal force should be applied in calculating the ultimate strength of a fly wheel to resist centrifugal force or actually make such misapplication of the rule that the resulting disrupting force shown, is over 4½ times as great as it should be, so it is believed that designs have frequently been based on the performance of other wheels, rather than the formulae in the books. Some of the more elaborate works on applied mechanics and the recent and most excellent work of Professor Thurston on the steam engine, however, contain a full discussion of the subject with resulting formulae which correspond, by changing the notation, to those hereinafter deduced without the aid of the calculus on the principle of fluid pressure. The errors used in the old formulae were fortunately on the safe side. All the rules agree as to the value of the centrifugal force due to swinging a single weight around a center, as in slinging a stone, and all will show the same strain on the string of the sling. The centrifugal force in this case is, as is well known, equal to the weight multiplied by the square of the velocity of such weight in its circular path in feet per second and divided by 32.16 times the length of the string or the radius of the circle. 32.16 is the value of the acceleratrix of gravity, usually designated by g, for the latitude of 42°; 32.2 being more nearly accurate for the latitude of London. In designing fly wheels it is customary to consider that the rim is of itself sufficiently strong to resist disruption from centrifugal force without assistance from the arms. The desirability of doing this will be discussed later. The error introduced in many of the hand books arises from calculating the centrifugal force from the weight of the entire rim by the rule above given, whereas it is evident that only the weight of one-half the rim pulls against that of the other half to produce disruption along any particular diameter, so the result should be divided by 2,

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* A lecture delivered before the students of Sibley College, Cornell University, January 23, 1892.

and again the centrifugal force produced by each half rim is resisted by double the sectional area of the rim, or by the sections at the two ends of the diameter, so the result should be again divided by 2, or by 4 in all, to find the unit strain on this basis. This result is still, however, 57 per cent. too large, for the reason that all the elementary weights in a half ring do not act at right angles to any diameter to produce rupture, but each pulls radially outward, so the resulting strain is exactly the same as that arising from fluid pressure within the shell of a steam boiler. In the latter case the strain on the double thickness of shell is, as well known, equal to the pressure on one inch of width multiplied by the diameter in inches, so if we consider the rim of a fly wheel or any pulley as a series of segments connected together at their edges, each, say, one inch wide at the outer end of radius of gyration, the total disruptive force at any diameter is equal to the sum of the components of the centrifugal forces produced by all the segments in a semi-circumference, or to the centrifugal force produced by one segment multiplied by the diameter, and not by the semi-circumference. The disrupting force thus obtained is resisted by two thicknesses of metal, so the result must be divided by double the section of the rim in square inches in order to obtain the unit strain on the material. In a fly wheel or pulley rim, however, the section which causes the weight is also the section which resists disruption. The width of the rim makes no difference, as each inch of width increases the weight and also increases the section. This is also true of the thickness, except that increase of thickness slightly increases the effective diameter. It therefore follows that the force which will disrupt a fly wheel is independent of the actual weight, width, or thickness of section, and only varies with the tensile strength of the material, the unit weight of the same and the square of the velocity.

FORMULÆ FOR CENTRIFUGAL FORCE APPLIED TO FLY WHEELS, ETC.

W = Weight considered in pounds.
W_1 = Weight of segment of rim one inch thick in pounds.
Q = Centrifugal force in pounds.
Q_1 = Centrifugal force of segment one inch thick in pounds.
S = Strain per square inch of section in general in pounds.
S_1 = Strain per square foot of section in pounds.
S_2 = Strain per square inch of section of cast iron in pounds.
S_3 = Strain per square inch of section of wrought iron in pounds.
S_4 = Strain per square inch of section of steel in pounds.

A = Area of rim section in square feet.
v = Velocity in feet per second.
V = Velocity in feet per minute.
r = Radius of gyration in feet.
G = Weight of metal per cubic foot.
F = Disrupting force in pounds.
g = 32.16 = Acceleratrix of gravity in pounds.

$$(1).\quad Q=\frac{Wv^2}{gr} \qquad\qquad (3).\quad v^2=\frac{V^2}{3600}$$

$$(2).\quad W_1=\frac{GA}{12} \qquad\qquad (4).\quad S_1=144\,S$$

$$(5).\quad F=2\,AS_1=2\,r\times 12\,Q_1=\frac{2\,r\times 12\,W_1\,v^2}{gr}$$

$$(6).\quad S=0.00000006\,GV^2=\frac{6\,GV^2}{10^8}$$

$$(6a).\quad S_1=\frac{G\,v^2}{g}$$

For cast iron $G = 450$, so

$$(7).\quad S_2=0.000027\,V^2=\frac{27\,V^2}{10^6}$$

$$(8).\quad V=192.5\sqrt{S_2}$$

$$(8a).\quad v=\sqrt{\frac{g}{G}S_1}$$

For wrought iron

$$(9).\quad S_3=1.067\,S_2.$$

For steel

$$(10).\quad S_4=1.088\,S_2.$$

Referring to the notation and formulæ above, Eq. (1), will be recognized as the general formula for centrifugal force. The velocity, it will be understood, is that due to a diameter equal to the double radius of gyration of the section, or for approximate work to the external diameter of pulley less the average thickness of rim. By Eq. (2) the weight of a segment or radial slice one inch thick at end of radius of gyration equals the volume, or $\frac{1}{12}$ of the area in square feet multiplied by the weight of one square foot. By Eq. (5) the disrupting force, F. is made equal to twice the section, A, of rim multiplied by the tensile strength, S_1, of material, which result equals twice the radius *r*, or the diameter, multiplied by 12 to reduce to inches into the centrifugal force Q_1, due to a single segment, on principles above explained. The value of Q is substituted in the last member from Eq. (1), writing W_1, for W. By combining with Eqs. (3) and (4) we easily obtain Eq. (6), and substituting in the weight $G = 450$ of a cubic foot of cast iron we observe from Eq. (7) that the tensile strain, S_2, per square inch of section of a cast iron rim may be found by multiplying the square of the velocity of the rim in feet per minute by 27, and pointing off six places of decimals. Eq. (8) is evidently derived from Eq. (7). Wrought iron and steel are a little heavier than cast iron, which may be considered by the corrections stated in Equations (9) and (10). In Eqs. (6) or (7) by making S or S_2 equal to the ultimate tensile strength of the materal, the value of V will represent the velocity at which the rim should be disrupted. While good gun iron has a tensile strength of 40,000 pounds per square inch and upward, and ordinary castings generally have a tensile strength of 15,000 pounds, it is thought best to consider the ultimate tensile strength of cast iron pulleys as 10,000 pounds per square inch, for the reason that pulleys cast in one piece are subject to internal strains, and even fly wheels and pulleys built up of pieces are liable to have blow holes in some part, and generally also the fastenings are not equal in strength to the solid rim. On the basis of 10,000 pounds tensile strength the rim of a cast iron wheel should, according to Eq. (7), be disrupted when its velocity has reached 19,235 feet, or 3.64 miles per minute. Ordinarily the rim velocity of fly wheels is less than a mile a minute, but in some cases it is higher. With 6,083 feet or 1.15 miles per minute the strain on rim is only 1,000 pounds per square inch of section. Evidently if this is practically the limiting strain used for a cast iron fly wheel rim, it should not be exceeded on a cast iron car wheel, the better material used being required to offset the effect of jars and internal strains due to chilling the faces. Cast iron car wheels should not, therefore, be run at a higher speed than 1.15 miles per minute or 69 miles per hour. The factor of safety at this speed for both the fly wheel and car wheel would be 10 to 15 for 10,000 to 15,000 pounds tensile strength. The same factor of safety for a wrought iron or steel rim would permit a unit strain of 5,000 pounds per square inch and a rim speed of 201 miles per hour, so that the dreams of the electrical engineers need not be disturbed by fears of the influence of centrifugal force, at least if kept within the limits of doubling or even more than trebling the present speeds of railroad trains.

Recurring to the effect of the arms of a wheel on the result, it should be borne in mind that they are also influenced by centrifugal force, which increases with the weight required to increase their strength. If it be considered that the outer attachments of arm to rim of a built up fly wheel are such that the center of gravity of the arm is at half its length from center of shaft to rim of pulley, the united strain will be exactly half that shown in Equations (6) and (7) for the rim, so by calculation half the strength is available to strengthen the rim, or a trifle more if the fly wheel centers are relatively large. The arms, however, are subject to transverse strains, if not from belts at least from changes of speed, and there is, moreover, no certainty that the arms and rim will be adjusted so as to pull exactly together in resisting disruption, so the plan of considering the rim by itself and making it strong enough to resist disruption by centrifugal force within safe limits, as is assumed in the calculations above, is altogether the safer way.

The destructive energy developed by the disruption of a large fly wheel is illustrated by a very complete set of photographs of the ruins resulting from the destruction of a large fly wheel in the Amoskeag Mills, at Manchester, N. H.. which took place on the 15th of October, 1891, the photographs being kindly furnished by Past Assistant Engineer Charles H. Manning, U. S. N. (Retired), the Superintendent of the Company. This Company has a series of mills distributed along both sides of the Merrimac River for a distance of a mile and upward, the machinery of which is operated by water power during the season the same is available, and by large engines at other times. Much of the time the engines are connected to part of the water wheels and supply any deficiency in the power of the latter. The engineering features are on a large and interesting scale. For instance, a large boiler house is located on the west bank of the river, from which steam is conducted through a pipe laid across the river on a special bridge to engines on the east side, and the exhaust brought back through another pipe on another bridge. The engine to which the accident occurred was of the double Corliss condensing type, with 36 inch cylinders, rated at about 2,000 horse power. The steam pressure was 95 pounds per square inch. The normal speed of engines was from 60 to 61 revolutions per minute, and they were furnishing just previous to the accident, 1,900 to 1,950 horse power, independent of a light water power connected to the same shafting, which was considered, under the conditions, insufficient to materially increase the speed. The fly wheel was 30 feet in diameter and had something more than 9 feet face. It carried three belts, one 24 inches wide running to the westward and connecting to a jack pulley on a shaft leading northerly to operate mills 7 and 8, the other belts each 42 inches wide, arranged on either side of the former, running to the eastward and connecting to two separate jack pulleys on a shaft leading southerly and operating mills Nos. 3 and 4. The first difficulty observed was the slowing of the speed of the looms in mills 3 and 4 due, according to some accounts, to some derangement of a tightening pulley on one of the 42-inch belts. The operatives, therefore, as per standing orders, stopped the machinery, which, according to the finding of the coroner's jury, relieved the engines of 1,500 horse power which caused them to accelerate their speed, the governor not controlling them as promptly as was customary. This increased speed quickened that of the looms in mills 7 and 8, and all but one were automatically thrown off, thus relieving the engine of 300 horse power more and causing the speed to increase still more. The engineers quickly detected the increased speed and commenced closing the throttles, but when one was entirely closed and the other practically so, the fly wheel was suddenly disrupted, killing one of the engineers, wounding another and cutting a broad swath in the roof and walls of the engine room and those of an adjoining building to the westward, the basement of which was used as a pump room, and the upper part as a "drawing-in" room, and causing the death in the latter room of two operatives. Let us approach these buildings from the outside, first looking at the west side of the pump and drawing-in building in which the operatives were killed. The result of the accident was, that a broad opening like a portal was cut through the wall of this building as well as through the wall of the adjoining engine room. The large pipe at the foot of the break is the main exhaust pipe used for heating purposes, which may be utilized as a steam pipe from the boiler house across the river via the north bridge.

We then look from the outside at the east side of the engine room. Here the destruction is more complete. A broad opening is cut in the wall and roof, and we see that a portion of the latter on either side of the cut has tumbled in. We see in the background the top of the large opening previously observed in the west wall of the pump and "drawing-in" room.

We now step inside the engine house and look from a point considerably to the left of the engines, where the opening through the west wall is not in sight, and view the wreck. On either side fragments of the roof still remaining in place are seen, and the ground is strewn with bricks, timber and material of all kinds. The large vertical pipes to the background at the left belong to the Buckley jet condenser, in which the vacuum is produced by a tall water column instead of an air pump.

It has been previously stated that one loom in mills 7 and 8 did not stop. Careful tests were made with this loom to ascertain the speed at which the automatic stopping apparatus would operate, from which the coroner's jury decided that such loom could not at the time of the disruption of the fly wheel have been making more than 170 to 175 picks per minute, corresponding to 72 to 74.1 revolutions per minute of the engine. According to the rule previously given for a cast iron wheel 30 feet outside diameter, or, say, roughly 29¾ feet, for the double radius of gyration, disruption should not have taken place at less than 205.8 revolutions per minute, even if the average tensile strength of the rim section was only 10,000 pounds per square inch. It is natural to suppose, therefore, that the wheel failed from defects in construction or material. The face was very wide for one set of arms, and therefore weak to resist lateral strain. There would have been some side strain if one only of the two 42 inch belts became slackened, but it would seem quite insufficient to cause the breakage. The disruption was, however, readily accounted for by defects in the castings. Very large blow holes were found in many of the same, and samples of the material varied in ultimate tensile strength from 15,000 down to 1000 pounds per square inch, showing clearly that the wheel had been running for a number of years with a dangerously low margin of safety, and that it was finally disrupted under an increase of strain of trifling importance in comparison with its supposed ultimate strength, and under conditions very much less exacting than those occurring regularly many times in a day or even in an hour with engines of a similar kind subjected to variable loads.

We will now turn our attention to a wreck caused by the disruption of the fly wheel of a compound Corliss condensing engine employed to operate a portion of the electric lighting machinery in the electric station of the Electric Light & Gas Company of Lynn, Mass. The engine was provided with cylinders 20 and 36 inches in diameter each with 48 inches stroke of piston and connected to a crank at one end of the fly wheel shaft. The surface condenser was the Wheeler independent form with independent circulating and air pump, the station being near an arm of the sea. The fly wheel was 20 feet in diameter with 40 inches face, and was said to weigh 38,000 pounds. It was belted directly to a jack pulley on a shaft near the center of the building, a little way in front of the cylinders. The passage in front of the cylinders was under the slack side of the belt and over the tight side which ran underneath the floor at that point. The jack shaft was continued by several lengths of line shafting connected by friction clutches and carried pulleys belting directly to the dynamos. The accident occurred in October, 1890, in connection with a small fire in the tower of the building from which the conductors for arc lamps were carried out to the pole lines. The nature of the destruction was very similar to that which occurred at Manchester, a swath being cut through the roof and both sides of the building, and at least one piece of the fly wheel was carried fully 150 feet horizontally across a vacant lot and a railroad track, wrecking the corner of a house and falling alongside the cabin of the watchman at the railroad crossing. Fortunately no deaths resulted from this accident, though two men were temporarily injured by flying pieces. Interest in the case has been renewed by a suit brought by the Electric Company against the insurance companies for reimbursment for all the damages that occurred, not only from the fire directly but those due to the wrecking of the engine. In connection with Mr. Manning, of the Amoskeag Mills previously mentioned, and Mr. C J. H. Woodbury, Vice-President of the Boston Manufacturers' Mutual Fire Insurance Co., the speaker was engaged as an expert by the insurance companies. It is thought that it will be of interest to briefly state the points claimed by each side in this very interesting litigation, for the reason that all were dependent on electrical and mechanical engineering principles combined in an unusual way.

The insurance law in Massachusetts is understood to be that insurance companies are responsible not only for the fire but for all damage directly occasioned by the fire. The burden of proof is, however, on the insured to show that the losses other than those from the fire itself were actually occasioned by the fire. The plaintiffs in this case did not, therefore, attempt to account for the fire in the first instance, but endeavored to show that such fire caused all the damage, they claiming that the fire caused a short circuit in the tower by enveloping the plates of the fire arresters in flame and possibly expanding them so that they came in contact. They claimed that this short circuit was brought on so suddenly that it broke the pulley operating the dynamos then in use, that pieces of this pulley flew and hit others, and, according to one phase of the theory, one of the pieces broke off one ball of the governor so that the engine ran away and caused the damage, and according to another phase, providing for the fact that the loss of one ball would not disable the governor, it was assumed that the jar due to breaking the first pulley caused the next pulley to break, and that the next, and so on from pulley to pulley across several undisturbed bearings and a friction clutch attachment, a distance of about 30 feet, until the jack pulley was thus broken, and that then pieces of this were carried by the belt under the fly wheel and broke that, causing the wreck.

On the part of the defendants it was only necessary to disprove the probability of the assumptions, but in addition affirmative proof was presented to show that the conditions indicated a defect in the governor belt and that the damage to the machinery was simply due to the running away of the engine. The disaster occurred between 1:30 and 2:00 a. m. when current was being supplied for only 95 arc lights and for incandescent lights in the station. The arc lights were operated by two 50-light Thomson-Houston dynamos, such lights being distributed in four circuits from the station, which were, however, coupled two and two in series so as to form one circuit for each machine. Both dynamos were operated by one pulley on the line shaft, the belt to the pulley of the farther dynamo running over the driving pulley on the top of the belt from the other dynamo. A similar pair of dynamos were running on open circuit at the time, and in addition an alternating dynamo and exciter for the same were in operation to light the station. There were at the time only two men in the engine and dynamo room and a third man in the fireroom adjoining. The testimony of all was to the effect that one discovered the fire in the tower, and that another who was busy wiping shafting came and inspected it. The statements were to the effect that up to that time everything was working smoothly. It was stated that one called out to the fireman to blow the whistle, and then turned on the fire alarm near another entrance to the building, and that the watchman, after inspecting the fire, went to the throttle valve of the engine. It was claimed that suddenly there was a tremendous roar indicating a short circuit. The evidence of the fireman would imply that the roar continued for some time, but the testimony of the engineer was to the effect that coincidently therewith the pulley driving the two dynamos went to pieces and that immediately other pulleys commenced to fly and that he left the building. The watchman claimed that he had started to shut steam off the engine, for a reason not clearly explained, but that the pulleys commenced to fly and he, though struck by a flying fragment, bounded over a gate out of another exit.

All the experts agreed that the first effect of short circuiting a Thomson–Houston arc dynamo is to materially increase the load, due to the increase of current, but that such load is very soon brought back to the normal by the action of the current regulator. The efforts of the plaintiffs were to show that the short circuit, being an electrical phenomena, brought an instantaneous shock on the dynamo, which was transmitted through the belts from the dynamos to the operating pulley on the main shaft. Instances were cited showing that a belt operating a dynamo had in several cases been run off in this way, and in one instance the belt became foul with the operating pulley in such a way as to crush it. An important point arose as to the time it required the dynamo regulator to act and reduce the current; several of the witnesses claiming that it required ten to fifteen seconds, and all agreeing that this time would vary with the condition of the apparatus and the amount of damping afforded by the fluid in the cylinder attached to the regulator. As a method of accounting for the short circuiting, the plaintiffs presented a diagram of the lightning arresters in the tower. There was one connected in each outgoing and each incoming conductor of each circuit, and as there were four circuits in use there were, therefore, eight lightning arresters involved. The four circuits were, however, as stated, coupled up at the time to make two, one for each machine; that is, the current going out from one terminal of the dynamo came back to the switch board instead of to the dynamo and was directed out on another circuit and brought back to the dynamo through the second terminal of the second circuit. To account for the short circuiting it was claimed that the fire filled the whole tower with flame, which, as it contains carbon, was a conductor and short circuited the dynamos by enveloping the segments of the lightning arresters. It was also claimed that in due time such segments became sufficiently expanded by heat to be brought in actual contact and thereby make a metallic short circuit. It was further claimed that fragments of carbon from the burning woodwork dropped between the horns of lightning arresters and thus short circuited them, and that in one or more of these several ways the several lightning arresters were connected to form a short circuit. In response, the defendants urged the improbability of any such action. Such a short circuit could only take place by grounding both branches of each circuit through two lightning arresters at the same time. The fire was localized in the vicinity of two of the arresters which were on the same circuit, but such circuit was connected in series with another, so that if short circuited it would only cut out about half the lights in the double circuit, or one-fourth of the whole. Two other lightning arresters of the four circuits were near and two more were on the opposite side of the tower where there were few signs of fire. It was clearly shown that to short circuit all the lights through the lightning arresters the segments of at least four widely separated must be in contact or the space bridged by flame or dropping sparks at exactly the same instant, and if this were done by flame it was necessary that the flames, which would naturally roll around and show alternately flame and smoke as in any fire, should form forks of conducting flame sufficient to form a short circuit at four to eight different points in the tower at exactly the same instant. Any less mysterious coincidence would only short circuit one pair of lightning arresters and cut out about half the lights on one dynamo, or roughly one-quarter of the whole, and if this operation were repeated shortly after, another quarter would follow, and so on, and instead of a sudden shock it would be a series of small shocks quite insufficient, even on the theory of the plaintiffs, to cause the damage. It was shown that the quadrants of the lightning arresters would be expanded at a temperature of 1200 degrees sufficient to be brought in contact, but it was difficult to suppose that the flame was at a sufficiently high temperature to expand all at the same time when the fire was confined to one corner of the tower. Ordinary flame has a temperature, according to the books, of 790 degrees, for the reason that currents of air are commingled with it in order to carry on the combustion with a material developing so much hydro-carbon gas in the process of combustion. Brass melts at about 1,950 degrees, and it is well known that brass cannot be melted in an ordinary wood fire, but requires a blast with charcoal or other solid combustible. The brass was not melted, so the highest temperature obtained in the hottest corner of the tower was therefore less than 1,950 degrees, and much less elsewhere. It was further claimed on the part of the defendants that the fracture of one pulley would not necessarily fracture the next one on the line, and that of the next and so on, and produce the train of breakages in the order claimed by the plaintiffs. The plaintiffs showed that one of the piers of the line shaft alongside the first pulley that broke was fractured, and claimed that this was done by that pulley fouling at the time of the short circuit, bringing a jar on the pillow block, which caused the disruption of the next pulley and that in turn the next, but this was answered by the fact that no other pier was injured and that no great shock could be transmitted beyond the next journal. There were two journals before reaching the two on either side of the jack pulley, neither one of the four being disturbed, and a friction clutch intervened. The defendants claimed that the pieces of the first pulley which it was in testimony, flew up and struck the ceiling and the switch board could not in the limited height available spread very greatly, and that therefore no piece of the first pulley could fly off at an angle of 40 to 45 degrees for a distance of about 40 feet and break the governor of the engine at the outset, and it was stated that if it did the engine would still be under control.

It is possible that failure of a pulley or fly wheel may commence nearer one edge than the other and thereby tend slightly to disperse the pieces, but the breakage entirely across the face would follow so nearly at the same instant that the component of force due to the velocity in the plane of the wheel would be much the greater, and only such of the flying particles as flew high in the air could disperse laterally any considerable distance. Any piece that was thrown straight up after the roof or other obstructions had been removed would, at a velocity of 19,235 feet per second, rise to a height of nearly 1,600 feet or, say, over 1,000 feet allowing for the resistance of the air, and such piece in falling, if diverted to the slightest extent, might reach to a considerable distance laterally, though such a result would be prevented by obstructions in a building. One of the most interesting experiences during the bombardment of Forts Jackson and St. Philip, on the Mississippi River, during the war, by the Porter bomb fleet, as told by soldiers of the southern army afterward, was the way in which the pieces of shell scattered. In most cases the shells coming down vertically buried themselves in the mud and merely threw up a large volume of it, causing a general scattering of the groups of soldiers for the moment and a laugh afterward. Sometimes men playing at cards would run like mice to the casemates and avoid the direct result of an explosion and then be back as quickly to their positions in the game, and on several occasions after they had all returned and were laughing over the last Yankee shot and noting the discomfiture of some one who was covered with mud, they would be startled by a sudden whirr and the "lazy piece," as it was called, would come back from the skies and perhaps injure one or more of them.

The "lazy piece" meant one thrown vertically upward at the time of the explosion and which, therefore, being unobstructed rose to a great height and took considerable time to rise and return.

It was also claimed by defendants that if the jack pulley broke before the main fly wheel and pieces of the former were carried on the belt underneath the latter, the upward strain would not necessarily break the fly wheel, or at least not without breaking the frame of the engine or the pillow blocks, cap or bolts, which was not the case. The plaintiffs showed that the frame of the engine had been racked, but this the defendants accounted for by the shaking of the engine on its bed when running away.

The defendants, the insurance companies, after answering the theories of the plaintiff, claimed that the whole accident was caused by the running away of the engine, due to the slackness of the governor belt or the slipping out of the lacings, whereby the governor acted rather slowly or entirely ceased to act. No safety attachment was provided for such an emergency, but the engineers have applied one since the accident As to the cause of the fire, it only required a little moisture on the wood of the tower to which the lightning arresters were screwed to cause a slight leakage between the terminals of the dynamo when a very moderate increase of electro-motive force would cause additional current to cross the shunt formed by this leakage and char the wood so that it would become a good conductor and thus form a short circuit, which, though only throwing out, say, one-fourth the lights, would start the wood work in a blaze and cause the slight damage by fire in the tower, which apparently cost only about one hundred dollars to repair.

It was in evidence that the governor belt was new, though this was denied by the engineer in charge. An engine controlled through a governor belt with the lacing coming out would accelerate speed quite rapidly, and the speaker claimed that if the current regulator of dynamos required ten to fifteen seconds after a short circuit to control the current as claimed by plaintiffs' experts, it would also fail to promptly control the current due to a rapid increase of voltage from rapid acceleration of the speed of the engine and dynamo and cause a short circuit and the fire, and that at any rate it was doubtful if the regulator could control the current within unusual limits such as would obtain if the speed of dynamo were doubled, or much less if it raised from 850 to over 3,000 revolutions per minute, as would have been the case if the engine ran away. In answering this the Thomson-Houston expert made another close distinction, as he claimed that though the regulator was slow in checking an electrical phenomenon like a short circuit, still, being itself operated by electricity, it really changed at a faster rate than it was possible to cause a mechanical change, such as an acceleration of the engines. This by no means follows, as it will be shown that the engine would quadruple its speed and that of the dynamos in seventy seconds or less, according to the work being done. The Thomson-Houston expert, however, acknowledged that it was doubtful if the regulator would control the current when the speed of dynamo increased to more than 1,700 revolutions per minute. The insurance companies also put in the evidence of an electrician that one of the station transformers was burned out, indicating increased speed of the alternater and exciter, but the other side denied this. The plaintiffs put in testimony that any increase of speed would have been noticed at the start, but evidently men occupied with a fire might not observe it. The roaring noise heard by the fireman could not have been that due to a short circuit which instantaneously caused the break on the theory of the plaintiffs, as the noise and the breakage were, according to such theory, coincident and over in an instant. A man who was called from the fireroom, therefore, could not have heard the roar, so-called, of a short circuit before the breakage occurred. He could, however, have heard the increased buzz due to the more rapid passage of the gaps between the commutator segments under the brushes. The defendants naturally suggested that the men did observe that the engine was running away, and that the watchman went to the throttle valve for that reason and commenced closing it, but by that time the speed was so great that the pulleys of largest diameter on line shaft were being disrupted by centrifugal force, and it is probable that the one driving the dynamos being slightly distorted by regular strain was the first one to go and that the others of same diameter on the line shaft followed in succession. The acceleration of speed once started could not be controlled by the governor belt, so the speed increased until the main fly wheel was disrupted by centrifugal force, breaking the jack pulley, throwing down the roof of the building and cutting a gap in the roof and sides.

The plaintiffs claimed that if the speed of the alternater and exciter increased, the lamps would have been brighter, but evidently the men would not have noticed this if occupied with the fire. They also claimed that since the rim speed of the armatures was greater than that of the pulleys they should have been disrupted first, which was answered by the statement that the materials of the armatures were of higher tensile strength. In fact, the globular shape of the armatures of the arc light T. & H. machines is well adapted to prevent any injury to the winding by centrifugal force, and the wrought iron cores of the spools in the alternater were evidently able to resist much more speed than any cast iron construction. Tests were made by the plaintiffs to find if a governor like that on this engine would regulate with one ball in use. The sleeve lifted by a governor of this size was quite heavy, so it was found that the speed of engine under such circumstances would have been increased to about 118 revolutions per minute, but even this was well within the safe limit even of the pulleys with the most rapid rim speeds.

The speaker made calculations to determine the speed at which the engine and several pulleys would be disrupted by centrifugal force. The normal speed of the rim of the fly wheel at the diameter of the approximate radius of gyration was 4715 feet or $\frac{8}{10}$ of a mile per minute. The rim speed of the jack pulley must therefore have been substantially the same, or a trifle less on account of slip, and the rim speed of the 6-foot pulleys on the shaft operating the dynamos as well as the rim speed of the pulleys of the dynamos themselves have been about 50 per cent. greater than that of the fly wheel. From the formula above given it was calculated that for a tensile strength of 10,000 pounds per square inch the fly wheel should have been disrupted at 310¼ revolutions per minute, or, roughly, four times the normal speed. The 6-foot pulleys on the jack shaft should, however, have been disrupted when the engine was running at a speed of 207 revolutions per minute. In order to ascertain approximately the time it would require for an engine under these conditions to run to destruction in case the governor belt were entirely disabled, it was assumed that even with the increased draft on steam pipe, due to running away, a mean pressure of 48 pounds would be obtained, referred to the large cylinder. By "referred" we mean simply that the mean pressure in the small cylinder, divided by the ratio of the area of the two cylinders, is added to the actual pressure in the large cylinder. This mean pressure was sufficient to give 900 horse power at normal speed, and of course the power increased with the speed. It was, however, considered that 13.5 lbs. mean pressure out of the 48 were required until the first pulley broke to operate the dynamos and shafting, this pressure being sufficient to produce 253 horse-power at normal speed, which is probably a liberal allowance. The mean pressure of 48 pounds is also well within limits, at least for the initial increase of speed, so the time stated hereafter as required to destroy the wheels is probably somewhat greater than would be the case in practice. To ascertain such time it was considered that not only the fly wheel but every pulley connected therewith, as well as the armatures of the dynamos, really formed fly wheels which would require force either to accelerate or retard their velocity. To ascertain the effect on the result, the revolving weights of each were ascertained or estimated and multiplied by the ratio of the speed of same to that of the fly wheel. The sum of these quantities showed the additional weight which it would require in the fly wheel rim to produce the same result. It was found that the aggregate result was the same as if 10,120 pounds had been added to the fly wheel rim, making it weigh practically 48,000 pounds instead of 38,000. On this basis it was calculated that it would require 45 seconds for the engine to increase its speed from 76 revolutions to 207 revolutions, when, on the basis of 10,000 tensile strength, the pulleys on the line shaft should have been disrupted, and as the disruption of such pulleys would have reduced the load on the engine, with the exception of friction, it would only have required 27 seconds, or in round nnmbers 1⅛ minutes from the beginning, to raise the speed to 310¼ revolutions per minute and disrupt the fly wheel. There was testimony in the case to the effect that the engineer on watch confessed to his brother engineer that when the fire in the tower was discovered, he pulled the plugs cutting out the arc lights and thus released the load on the dynamos. With this state of facts the load on the engine would have been released earlier and the time required to run to destruction have been diminished. If, however, the governor belt was not broken, but simply slack, so that it took care of changes of load slowly, the acceleration could have progressed at a much less rapid rate.

From what has been stated it will be seen that the combined mechanical and electrical conditions involved in an accident to an electric light plant involve even greater refinements and complications in tracing cause and effect than has heretofore been the case with simple mechanical questions. It will also be observed that a very important question of principle arises in relation to damages occurring in connection with a fire, but not actually caused by the action of the fire itself. It has become necessary in many of the States by law and judicial decisions to exclude what are called "consequential damages," particularly in relation to public works, and this was founded on precedents long established in the older countries. For instance, under the common law a man in digging on his own land was not responsible for damages to a building on adjoining property. It is well understood that a man who fails to pay a debt is only liable for the amount of the debt and interest, although his delay may have caused failures which injured many other persons. So, also, in case of accident, or in fact of any injurious change of condition, there is always a direct result followed by others more or less indirect also in the nature of damage. The indirect results are so far reaching, a damage to one causing more or less injury to another, that litigation would never cease unless some legal estoppel were put upon it, as has been done in relation to many kinds of transactions. Evidently, occurrences of a kind like that in the electric light station will have the effect of causing some such limitation in regard to insurance. If a fire which caused a direct damage of only $100, by fire, and immediate injury to only a few hundred dollars of fixtures in the neighborhood, can in addition be charged with the cost of injuries caused by a runaway engine, there might conditions arise where still further consequential damages would go on almost without end. For instance, questions of personal injury might be involved from many people struck by flying fragments, or a large fragment might knock down a drawbridge in the vicinity and wreck a train of cars, or such a fragment might strike a vessel loaded with explosives and cause a gunpowder or dynamite explosion which would wreck the whole neighborhood, and if such explosives were required for use by a then friendly government and that government failed to prevail in an impending war for a lack of such material, the one hundred dollar fire in the beginning might cause international complications and result in a general war. Somewhere in the progress from first cause to final effect the law of consequential damages should, and will sooner or later, be made to apply, and special policies will be written when accidents to machinery are to be included. Without anticipating what will be done, it would seem natural to limit the damage at a point where the carelessness of the employees or of the insured, by defects in mechanism or material, caused the increased damage. In the case under discussion the Judge ruled, for the purposes of the trial, that, even if the pulley was defective which it was claimed broke first, so that it broke with less strain than such pulleys should, still the insurance companies would be liable. Evidently if this were the case any slight accident, such as short circuiting the electric lights outside but near the station, or the dropping of a tool in some part of the machinery, might *without fire* have caused the other more important damages. It therefore appears equitable that at such a break in the chain as this, a limitation of damage arising from fire should be made, on the general principles that have made it necessary to provide limitations in other cases, and also on a principle like that of contributary negligence in case of personal injury, whereby it would be provided that whenever the insured were themselves also at fault, either through the action of their employees or by the use of defective machinery, which would be liable to cause such accident without fire, the damage from fire should be limited at that point. Who knows but what the courts may finally hold that this is a fair interpretation of the law as it stands ?

THE FINAL IMPROVEMENT OF THE STEAM-ENGINE.*

BY DR. R. H. THURSTON.

The progress of the steam engine in the century since the days of Watt and its application by him and his contemporaries to the innumerable purposes of modern life, has been mainly one, as the writer has often remarked, rather in the direction of refinement upon the construction of that great engineer than of introduction of any very great and novel inventions, or of radical changes in methods of operation. A study of the history of this progress during this period will show that no one really new principal invention has been made in the whole century. The simple and the compound engine were known at the beginning of the century ; and modern development has merely increased the number of the cylinders employed in series, and adapted the various modifications of the original to the now tolerably well-ascertained conditions of their best employment. The economical expansion of steam was a device of Watt, and Corliss and his thousand successors and imitators have only improved upon the mechanism of application of that principle as proposed by the pioneer inventor. The details of construction have been, by the steady application of the brightest minds of the century in that department of human activity, given symmetry, precise adaptation in forms, proportions and strength, to their special purposes; the machine as a whole has been given best proportions for use in stationary, locomotive, and marine engineering, and more and more perfectly suited to the advances constantly in progress in increasing steam-pressures, engine speeds, and ratios of expansion. In its principal features, the steam-engine of to-day is the engine of James Watt, brought, by the refinements of design and construction and the use of the new improvements in tools and the trades, to a perfection of construction and accuracy of apportionment to its work that was undreamed of in Watt's time.

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*From Proc. U. S. Naval Inst., Vol. xvii, No. 3, 1891.

So much of improvement as has been effected in the economical operation of the machine, in the improvement of its technically so-called "efficiency," has come in the increase of steam pressure, with its concomitant increase in ratio of expansion, and in engine-speed, reducing the thermodynamic wastes, the internal losses by cylinder-condensation, and the percentage of work wasted by friction of the machine itself. Every fact and principle of the modern engine would be perfectly familiar to Watt, were he to return to inspect the work of his disciples. So effectively have these improvements been applied to the development of the better class of modern engines, however, that the real is approaching wonderfully near the ideal in its highest efficiency, and the margin left for further gain has been brought down to a small fraction. When, with pressures of from 100 to 150 pounds of steam, the weight of feed-water per horse-power per hour is brought down to from 13 to 15 pounds, the inventor and the designer alike feel that their occupations are losing their attractiveness.* It becomes, however, especially interesting and important to ascertain what is the extent and the character of the wastes remaining to be reduced or exterminated. A careful study of the case shows that, with the best engines, this total waste, apart from the distinctively thermodynamic and, so far as known, unavoidable rejected heat, the energy lost consists of three principal parts: (1) heat lost by conduction and radiation externally; (2) heat wasted by conduction through the action of the metal of the cylinder internally ; and (3) the waste work of friction of engine. Of these the first is already reduced, in all good constructions, to an insignificant amount, rarely exceeding five per cent. ; the last has been brought down to five per cent. in non-condensing engines, in some cases to less than five per cent. and in condensing to ten, and will, when the oil-bath system of lubrication has been perfected and applied to such engines, be made much smaller still ; and thus the main and only large waste to be still fought against is the second kind, the waste by alternate sortage of heat in the metal of the cylinder and its later re-transfer to the rejected fluid passing into the condenser or out into the atmosphere.

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* Engines designed by Mr. Edwin Reynolds have certainly fallen within the smaller of these figures. See report by Mr. Henthorn, presented at the last meeting of the American Society of Mechanical Engineers, on the tests of engines of the Narragansett Electric Lighting Co.

It has now become well understood that the recognized advantages of jacketing, of superheating, and of compounding engines, are due to their effectiveness in the reduction of this waste. It has also become a familiar fact that neither of these expedients is more than a system of alleviation of an evil which neither can completely cure. Of the three methods, that of superheating is considered by the majority of writers on the subject and probably also by better authorities, the practitioners, to be that which promises, if it can be successfully applied, highest success. Unfortunately, up to the present time at least, every attempt to take advantage of the promised improvement in efficiency by this method has resulted unsatisfactorily in consequence of the ill-effect of the highest heated steam upon the lubricants and the rubbing surfaces of the cylinder. It has not been and is not now practically useful. Jacketing and compounding, separately and in conjunction, have proved more satisfactory ; but there remains, in the very best of engines, a considerable margin for further improvement. Some other system must apparently be tried if we are to see the range between the real and the ideal engine narrowed much more, or rendered unimportant.

The one as yet unsuccessful but obviously correct method of annulling cylinder-condensation is the reduction of the heat-storing power of the walls of the cylinder. Reduction of the heat-transferring power of the steam would answer the same purpose ; but that means superheating, apparently, and this is as yet impracticable ; though it is to be hoped that it may not always remain so. The reduction of the heat-storing power of the cylinder wall may come of reduction of its conductivity, or of its specific heat, or of the reduction of both these quantities. Many attempts have been made, for a century past, to accomplish this patent and simple result. But these attempts have been, thus far, as unsuccessful as those made in the other line.

Smeaton began this series of experiments on the old Newcomen engine of his time, and lined its piston surfaces and cylinder-heads with wood. But wood is too unsubstantial and too easily destroyed by the high temperatures of modern engines to be likely to prove very useful or permanently utilizable. Emery, many years later, tried lining the interior of his engines with glass and porcelain ; but that class of materials is too brittle and falls to pieces under the alternations of temperature and pressure of the steam. Babcock and others have proposed and tried, in some cases, the use of bismuth and other metals of low conductivity and small specific heat ; but they have proved treacherous and their flow when hot, like lead on a roof, has defeated all attempts at increasing efficiency by their use. Finally the writer has proposed the scheme of making the surfaces of the cylinder-walls, so far as possible, incapable of storing heat by special treatment in such manner as to produce a veneer or varnish integral, if the term may be used in that connection, with the metal of the casting itself. It is to describe this possibly impracticable notion that this article is written, and to show what has been the result, up to date, of experiments made with this end in view. Many experiments have now been made to determine the effect of the treatment proposed by the writer upon the conductivity and heat-transmitting power of iron ; but it has only been within a few weeks that we have had any even tentative results of application to the engine.

Smeaton's experiments were the first in this field and he seems to have made it a practice, in the later years of his work, to cover the sides of the piston and the heads of his cylinders with wood, for the purpose, following Watt, of reducing the wastes due the conductivity of the material of which the cylinders were composed. James Watt had, in his models, a number of cylinders of wood, adopting that substance for the same reason. Smeaton and Watt were contemporary, and it is impossible to say which is to be considered the pioneer ; but Smeaton was experimenting on the Newcomen engine with a view to improving its proportions and increasing its economy as early as 1767, and was in the full tide of success in erecting them in 1775. It seems likely that he may have been aware of Watt's work in 1765 ; but, though of later date, his own work on the engine itself was the first actual construction of engines with con-conducting interior walls. James Watt enunciated the principle ; John Smeaton put it in most direct use.*

Mr. Charles Emery, in 1866, while engaged in the U. S. N.

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* History of the Steam-Engine ; Thurston, pp. 67–78.

† Transactions Am. Soc. Mech. Engrs., Vol. VII, 1885-6, p. 375.

experiments at the Novelty Works, New York City, found that three cylinders, each 18 inches long, and 1½ inches internal diameter, one of iron, one of glass and one of iron enamelled on its interior surfaces, and all carefully clothed with non-conductors, charged and exhausted like the engine-cylinder, received volumes of the steam in varying proportions, the glass being taken as unity, these proportions were 1, 1½ and 2, nearly; proving that, in that case, the iron demanded, in consequence of the action now technically known as "cylinder-condensation," as much steam for condensation as was measured by its own volume; while the enamelled cylinder was subject to only half as much waste, if it is assumed that the condensation in the glass cylinder may be neglected as unimportant. In another series of experiments, Mr. Emery found that, at the same pressures, about 20 pounds by gauge, where the steam was dried before entering the tubes, the difference was even greater, by several per cent.

Mr. Emery next undertook to determine the effect of this treatment upon the engine itself, and constructed a pair of engines of 8 inches diameter of piston and equal stroke, which had their parts in exact duplication. One of these was enamelled on the sides of the piston, the cylinder heads. and the interior of port-passages, as well as of the cylinder itself, the bore being reground to secure a tight-working piston. Comparing the performance of the two engines, it was found that a saving of 27 per cent. was effected at a steam-pressure of 75 pounds and a cut-off of 0.3. With 40 pounds steam, at a cut-off of 0.15 the saving was the same; at 25 pounds pressure and a cut-off at 0.36, the gain was 30 per cent. and over. Re-boring the cylinder and thus removing the enamel from the cylindrical surfaces, the gain was reduced to about one-half that previously observed. This latter experiment was subsequently repeated by Mr. Westinghouse on his high-speed engines, but without important result; which fact is interpreted by Mr. Emery to be due to the high speed of the engine, reducing the wastes so greatly that the further gain by the partial protection adopted became insignificant.

So far as the writer has observed, these are the only records of experiments of this kind published until very recently. It will be remembered that Watt found that his model Necomen engine used four times its own volume of steam at each stroke, wasting, in this sense, three-fourths of all that entered it. This waste was mainly saved in the wooden model. No record exists, so far as known to the writer, of the saving effected by Smeaton on the large engines constructed by him with non-conducting interior surfaces. He reports the average duty of 57 engines near Newcastle-on-Tyne, in 1767, as giving a maximum duty of 7.44 millions foot-pounds per bushel (84 pounds) of coals, the average being about 6 millions for the larger engines. His own engine at Lonf Benton, 52 inches diameter of cylinder and 7 feet stroke of piston, at 12 strokes per minute, gave a duty, on the same basis, of 9 5 millions.* Possibly, of this difference of two millions, or about 30 per cent. on the smaller duty, of the older engines, a considerable fraction may be attributable to the ingenious expedient by which Smeaton reduced the then enormous wastes.

In modern engines, these wastes are greatly lessened by the various familiar expedients and improved conditions giving immensely increased efficiency as compared with the older machine; but daily experiments show that we still lose from one-fourth to one-third in the best of engines, and often a very much larger proportion of the steam supplied, by this same persistent method of interior waste. Its elimination remains, as formerly, the great unsolved problem challenging the engineer whose duty it is to design and construct engines of high efficiency; and the financial advantage promised by its extinction is even greater to-day than in the time of Smeaton and Watt. We cannot, however, use wood in the presence of the steam of our day; enamelling is found to be attended with practical difficulties that probably preclude its adoption, and the employment of it is obviously out of the question. It seems necessary to find some new expedient which shall evade the objections inherent in the plans proposed or practised previously. If the cylinder cannot be constructed of a non-conductive material, and if a superficial veneering or coating separately made and applied will not answer, possibly a way may be found of giving the interior surfaces of the cylinder walls non-conductivity and low specific heat by other and unobjectionable methods. As the condensing action of the cylinder is known to be due to an exceedingly thin layer, very superficial treatment, if permanent, will suffice.

The plan adopted by the writer for reducing the heat-wasting power of the interior walls of the engine-cylinder was suggested by the curious effect of slow oxidation upon cast iron, as illustrated in the corrosion of the "channel ways" and other parts of the engine in the neighborhood of condenser and air-pump, where jet-condensation is employed; the current of hot water, mingled with grease and holding air in solution, after months of working, sometimes dissolves out the iron for a depth of a half-inch, or even an inch, leaving a plumbago.like mass which may be cut with a knife as easily as the lead of a pencil. Many years ago, when pursuing his studies at Brown University, and when the Hon. Senator Hill, now of Colorado, then a young and promising chemist, had charge of the laboratory of that institution, that now distinguished and opulent statesman was kind enough to examine this altered substance for the writer and found it to consist of a mass of iron-oxide and graphitic carbon, encaged in a sponge or comb of metallic iron, and with its specific gravity and specific heat, as well as its conductivity, reduced to a fraction of the same quantities in the original mass. It seemed therefore possible that, if this process and result could be utilized in the reduction, in a similar manner, of the heat-storing and transmitting power of the inner walls of the engine-cylinder, a surface could be obtained that would be ideal in this respect; while, being integral with the metal of the cylinder, it would not be subject to injury by changes of temperature or accidental separation from the iron by flaking off. It was further apparent that this spongy mass might possibly be saturated with resin, or other and more permanent material having still higher value as a non-conductor, and thus practically do away with the waste by heat-storage on all areas to which the process might be safely applied. It would be impracticable to use such a process upon the rubbing surfaces of the cylinder and the piston-rings; but, fortunately for our purpose, the wastes taking place in this manner occur mainly on heads and in the ports and a comparatively small proportion takes place on the rubbing surfaces. These are also smooth and polished by the action of the engine and thus probably are rendered less capable of taking up or yielding heat to be so wasted. Nearly half the total internal surface of the average engine and much higher proportion of the waste may be reached by this system if it prove practicable.

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* History of the Steam-Engine; Thurston, p. 69. Smeaton, Vol. I.

The first—and the most successful to date—of the now many attempts to effect artificially this conversion of the mass of cast iron into the desired non conducting substance was made by Mr. W. E. Partridge who brought to the writer, as the outcome of his experiment, a piece of stove-plate, completely altered into what looked like a mass of hard rubber, black, smooth and of low density, and precisely what was sought. This was made by immersion, several days, in a vat of common foundry "pickle;" but, curiously enough, this first result has never yet been reproduced by any process or any solution that has been tried, aiming at its duplication.

A series of experiments was very carefully made by Mr. P. M. Chamberlain, in the early part of the year 1890, and reported to the American Society of Civil Engineers at their July meeting.* The results were interesting as showing, mainly, the effect of the preliminary solution, and incidentally as illustrating the fact that the slightest coating of non-conducting substance may have an important effect upon heat-transmission. The method of investigation was to treat a specially made head for one of the "experimental engines" of the laboratories of Sibley College, measuring the change in quantity of heat transmitted through the head to the exterior and thus measuring the conductivity of the head, originally and after treatment. The calorimeter used for this purpose was carefully calibrated and the data obtained are thought to be accurate. The following are the figures reported as above :—

The outer face was smoothly polished, as is usual; the inside was simply smoothly faced-off in the lathe with the ordinary finishing cut. The inner face was tested under conditions described as follows:

No. Test.	Conditions of Inner Surface.
1.	As finished; greasy.
2.	As finished; greasy.
3. 4. 5.	Same; washed clean with benzine and dried.
6. 7.	Oiled with lubricating oil.
8. 9.	Washed clean with benzine.
10. 11. 12.	After exposure to nitric acid sixteen hours; then oiled with linseed oil.
13. 14.	Similarly treated with hydrochloric acid, and oiled after twelve hours' exposure.
15. 16.	Sulphuric acid, 1; water, 2; for forty-eight hours; then oiled, and allowed to dry twenty-four hours.

Rankine's formulae was employed in making comparisons: †

$$q = \frac{t' - t}{\delta' + \delta + \rho x};$$

in which t' and t are the temperatures of fluid on each side of the plate, δ' and δ are the resistances to heat-transmission through these surfaces, and ρ is the coefficient of internal thermal resistance, and which may be neglected as insensible here. The equation gives q the quantity of heat, in $B\ T\ U$, transmitted per square foot per hour.

Let Q = total heat transmitted, then for the case in hand,

$$q = \frac{3}{2}\,\frac{Q}{0.171} = 8.772\ Q$$

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*Transactions, Vol. XXIII, No. 444, 1890; "A practical method for reducing the Wastes of the Steam-Engine."

† Steam Engine, page 258.

The value of Q varied from about 5 550 *B T U* in cases 1 and 2 to 3 000 and 3 100 in cases 15 and 16, as shown in the table which follows :

No. Test.	Q.	$t' - t$.	$\sigma' + \sigma + \rho x$	Heat Units per sq. foot per hour, for each degree, $\tau - \tau'$.	
1	5550.9	236.0	0.004844	170	As finished—greasy.
2	5566.4	238.0	4874	169	" " "
3	5444.2	238.8	4854	165	" " washed clean with benzine and dried.
4	5139.3	239.1	5303	159	" " " " " " "
5	5055.8	239.8	5410	152	" " " " " " "
6	5523.9	236.4	4878	169	Oiled with lubricating oil.
7	5444.3	236.9	4962	168	" " " "
8	5620.4	233.7	4740	173	Washed clean with benzine.
9	5515.6	234.7	4851	171	" " " "
10	5101.9	236.6	5286	162	After exposure to nitric acid 16 hours, then oiled, linseed oil.
11	5439.7	335.7	4950	170	" " " " " " " " "
12	5581.8	235.6	4812	171	" " " " " " " " "
13	5347.5	234.3	4985	166	" " to hydrochloric acid 12 hrs., " " "
14	5741.1	233.5	4635	174	" " " " " " " " "
15	3020.	225.3	8279	113	" " " sulphuric acid 1, water 2, 48 hrs., then oiled,
16	3104.9	225.5	8503	117	varnished, and allowed to dry for 24 hours.

In the first four runs the gradual increase in resistance noted was attributed to the gathering of rust on the exterior surface, no oil being used to protect it from the water, and to the gradual loss of greasiness on the interior. In Nos. 3, 4, 5 no sensible change appears other than the gradual alteration just noted; nor is any notable result attained until the last pair of data are reached. It then becomes evident that treatment with drying oil, even after so short a period of exposure to acid and so short a time allowed for drying, has an exceedingly important effect in reducing conductivity and preventing heat storage and transmission.

Thus by even a superficial treatment with acid and oil, the saving of heat is 40 per cent.

$$\frac{8500 - 5000}{8500} = 0.40, \text{ nearly.}$$

The last column in the above table was computed subsequently by Professor Carpenter, when comparing his results, as given below, with those of Mr. Chamberlain. Incidentally the interesting fact will be observed that Chamberlain's finished plates gave 50 per cent. higher conductivity than Carpenter's plates, with "skin" left as taken from the foundry flask.

Carpenter's method of determining the extent to which conductivity could be reduced by this system of treatment, as reported to the American Society of Mechanical Engineers, was as follows:*

In making the experiments, a set of cast-iron plates was obtained, all cast at the same heat and from the same pattern, each measuring 8.4 inches by 5.4 inches by .45 inch thick.

Concentrated nitric acid was used, and two solutions in rain water were made—the first containing 1 per cent. of nitric acid by measurement, the second 5 per cent. of nitric acid. In each of these solutions three of the plates were placed in a horizontal position, and separated from each other by small blocks at the corners, so as to permit a free action of the acid. The solution was shaken and left for some time in an inclined position to permit any air beneath the plates to escape. The plates were left in these solutions, respectively, nine days, eighteen days, and forty days, at which time a test of the relative conducting power was made. A test was also made of the relative conducting power of a plate of cast-iron of the same dimensions and not treated, and also of pine wood of same dimensions as the plates.

The following method of testing the relative conducting power of the plates was adopted. A box, shown in section in Fig. 1, was made of boards an inch thick, with internal dimensions 8.5 by 5.5 inches and 6.5 inches deep. Near the center of the box and extending completely around on the inside, a strip of wood 5/8 by 1/2 inch was rabbeted in place, as shown in the sketch. The top of this strip, marked *D*, was made accurately parallel to the top of the box, and neatly fitted in place. A gasket of rubber packing was fitted to the projecting top of this strip. Two frames, made of hard wood, with a horizontal piece about one inch square, were securely fastened to the box, as shown in Figs. 1 and 2. From the horizontal piece, *G*, of each frame, two braces, *HH*, were set with the lower ends resting on the plates to be tested. These braces were cut of such a length that by forcing them into nearly a vertical position, a strong pressure was made to act on the corners of the plate to be tested, and no difficulty was found in producing a steam-tight joint. The plate to be tested was introduced in the box as shown in the sketch, thus forming a horizontal partition, *DD*. Into the portion of the box below the plate a one-quarter-inch pipe, *E*, was introduced, terminating near the center of the box; this pipe was connected by a rubber hose to a steam supply; on the opposite side and near the bottom of the box was inserted a one-half-inch nipple, *F*, for the discharge of the condensed steam. A thermometer, *DD*, was inserted in the steam chamber, as shown, and maintained in the same position during all the tests Water was put in the box above the plate, and the heat transmitted through the plate was measured by the increase in temperature of this water. To measure the temperature of the water, a thermometer, shown at *A*, was held in position by a cross-piece of one of the frames, the thermometer being kept with its bulb immersed and in the same position throughout all the tests by maintaining a mark on the stem opposite the lower edge of the cross-piece.

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*Transactions, Vol. XII, 1890, No. CCCXXI, page 174.

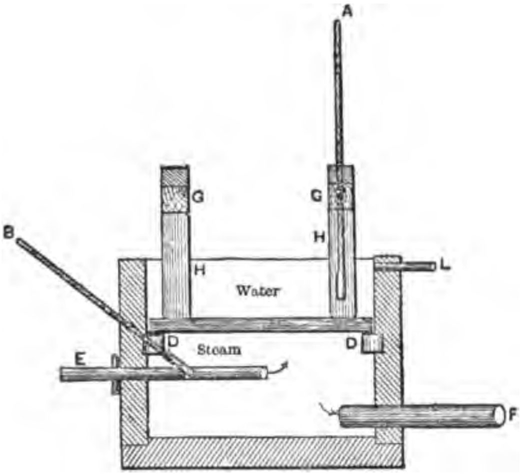

FIG. 1.

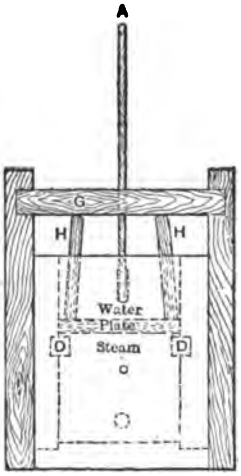

FIG. 2.

In making a test, the plate was first put in position, the box levelled, and steam turned on in the pipe *E*, with pipe *F* closed, until it was ascertained that there were no steam leaks around the edge of the plate. Steam was then turned off in pipe *E*, pipe *F* opened, the water was added in the chamber above the plate until it passed off in the overflow pipe *L*. Steam was then admitted through the pipe *E*, and as soon as the water above the plate reached a temperature of about 70°, readings of both thermometers were taken, and continued each minute until the water attained a temperature of about 150°. The temperature in the steam chamber could not be maintained quite uniform, as shown by the readings of the thermometer *B*. There was also a slight variation in the degree ot temperature at the beginning and ends of the different tests, but not enough to make any material difference in the results attained. The process used being exactly duplicated for each plate tested, gives the comparative transmission of heat for each plate, but does not give with exactness the number of thermal units transmitted, because of cur ignorance of the currents existing in the water chamber. Assuming no horizontal currents to exist, which is probably true, the average number of thermal units transmitted per inch of surface is equal to the weight of the water, 3.125 pounds, divided by the exposed surface of the plate, 38.7 square inches, multiplied by the rise in temperature; or .0807, multiplied by the rise in temperature of the water.

This can be reduced to thermal units transmitted per square foot per hour as follows, neglecting the coefficient of the internal thermal resistance:

Letting

K represent the number of thermal units transmitted per hour for each degree that the temperature of the steam chamber exceeds that of the water chamber,
τ represent the average temperature of the steam chamber,
τ' represent the average temperature of the water receiving heat,
a represent the effective area of the plate in square feet = .27 square feet,
w = weight in pounds of the water heated = 3.125 lbs.,
G = average gain of temperature of w. per minute,
g = average gain of temperature of w. per hour = $60\,w'$.

Then $$(\tau - \tau')\,aK = gw = 60Gw$$

$$K = \frac{60\,Gw}{(\tau - \tau')\,a} = 694.4\,\frac{G}{\tau - \tau'} = \frac{694.4}{\frac{\tau - \tau'}{G}}.$$

The results of these experiments are, in brief, as follows:

TRANSMISSION OF HEAT THROUGH CAST-IRON PLATES.

No. of Test.	Gain in Temperature per minute.	τ Average Temperature. Water.	$\tau - \tau'$ Average difference Temperature. Steam Chamber and Water.	Relative number of Thermal Units for each degree $\tau - \tau'$ per square foot per hour.	
1...	12.6	115.5	91.8	107.5	Clean cast-iron plate.
2...	15.0	120.2	88.2	114.8	" " "
3...	13.6	123.6	84.4	113.4	" " "
4...	14.7	123.4	86.4	118.5	" " "
5...	14.1	120.5	88.8	110.0	" " "
6...	13.7	126.0	83.2	115.2	" " "
Av.	......	....	....	113.2	
1...	11.6	127.5	81.5	97.6	Plate pickled 9 days in 1 pr. ct. solution nit. ac.
2...	10.4	128.2	77.9	91.8	" " " " " " "
3...	12.6	127.0	81.1	103.9	" " " " " " "
Av.	......	....	....	97.7	
1...	9.8	118.7	83.7	79.74	Plate pickled 18 days " " " "
2...	10.2	123.3	83.6	83.00	
3...	9.7	118.9	86.0	78.00	
Av.	9.7	....	....	80.08	
1...	9.4	119.2	88.4	73.5	Plate pickled 40 days in 1 pr. ct. solution nit. ac.
2...	9.4	128.2	80.8	80.3	" " " " " " "
3...	10.	121.9	87.1	79.7	" " " " " " "
Av.	9.6	....	....	77.8	" " " " " " "
1...	9.7	128.7	80.3	88.17	Plate pickled 9 days in 5 per ct. solution nit. ac.
2...	9.4	130.0	74.6	87.5	
3...	10.7	121.	86.5	85.1	
Av.	9.93	....	....	87.0	
1...	......	....	....	....	Plate pickled 18 days in 5 per ct. solution nit. acid. These results were unfortunately lost, but did not differ much from 80.0 ther. units.
2...	......	....	....	....	
3...	......	....	....	....	
Av.	......	....	....	....	
1...	10.9	117.9	92.6	80.3	Plate pickled in 5 per ct. sol. nitric acid 40 days.
2...	11.2	119.2	90.8	75.7	
3...	9.8	120.5	87.7	76.3	
Av.	10.6	....	....	77.4	

Comparing the data thus obtained, it is seen that the work of both these investigators gives evidence that the simple alteration of the surfaces, as proposed by the writer, may reduce their conductivity and heat receiving power as much as 40 per cent., and to that extent, presumably, reduce the interior wastes of the engines on so large a portion of the cylinder walls as it may be practicable to treat in this manner; while it is also seen that the application of a single coating of varnish to a surface less completely altered, as in the first series, may produce reduction of conductivity to about the same extent. The combination of effective treatment, as originally proposed by the writer, uniting both methods, and making the alteration of the metal a foundation for treatment with a non-conducting substance penetrating the sponges so formed, should still further improve the engine. The test of this proposition was made by Mr. Daniel Royse and reported to the American Society of Mechanical Engineers recently.* The following is an abstract of the paper:

The calorimeter used in making the comparisons is shown in section in the accompanying illustration (Fig. 3). The lower part is a pine box 4.5×7.5 inches and 4.5 inches deep, inside measurements, the plate through which the heat is to be transmitted forming the top. The upper portion consists of a frame or bottomless box 4.5×7.5 inches inside and 3⅞ inches deep which is placed above the plate, and covered with a lid as shown.

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* Transactions, Vol. XII, No. ccccxlviii, June, 1891.

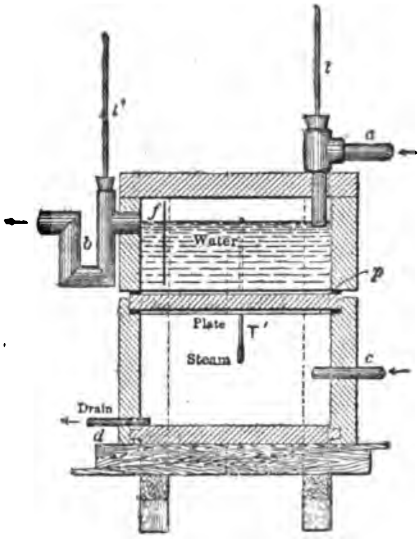

FIG. 3.

The lower compartment is supplied with steam through a ¼ inch pipe, c, and is drained through the pipe d. In one side a thermometer T' is inserted—making an angle of 45° with the vertical—so that the bulb is near the centre of the box. Above the plate, water enters through a pipe, a, placed in the lid, its temperature being taken by the thermometer, t, and flows over the plate and out at the pipe, b, the thermometer, t', registering the temperature at which it leaves; f is a tin baffle-plate.

The method pursued was to turn on the steam and water and after the temperatures as indicated by the thermometers became constant, note the time and weigh the water which flowed through in half an hour, reading the three thermometers at intervals of a minute.

Experiments were made upon nineteen plates, six prepared by Professor Carpenter, which were immersed in different acid solutions of various strengths for different lengths of time. Of these ten were rough and nine planed on both sides. Two others planed on one side were also used.

The depth to which any plate was attacked by the acid may be approximately computed by knowing its loss of weight and the extent of surface exposed to the acid. Each plate was 5.5 inches by 8.5 inches and the thickness was one-quarter inch or one-half inch, planed or rough, and the area of each was about 106 square inches. Since a cubic inch of cast iron weighs 0.26 lbs., a loss of weight of .01 lb. means that it has been attacked to a depth of $\left(.01 \times \frac{1}{.26}\right) \div 106 = .00036''$.

All plates prepared by Mr. Royse were immersed in a vertical position, there being 11 lbs. of the solution to 318 square inches of surface of iron. From the atomic weights of the elements involved, it was computed that in the 5% and 10% solutions only about one-third of the acid was consumed in attacking the iron. In all cases the effect of the treatment was to form a coating or scale, black in color, upon the surface of the plate. This presumably carbon or in the case of rough plates a mixture of carbon and silicates, was quite adhesive, but easily removed with a knife. Plates attacked by nitric acid, when removed, were black in color, while those which had been treated with hydrochloric or sulphuric acids were quite rusty when removed.

The loss of weight of the plates when immersed in the latter acids was about twice as much as when a nitric solution of the same strength was used.

It will be noted that the heat transmitted through untreated planed plates varies from 278.0 to 232.1 B. T. U. per square foot per hour per degree difference of temperature of the bounding fluids. Mr. Royse attributes this variation to some plates being rougher than others; to the rust which accumulated on the surface exposed to the water; and also to a different amount of the water of condensation clinging to the surface exposed to the steam during different experiments. In computing, all planed plates are compared with No. 1, which transmitted 278.0 B.T.U. Similarly rough plates are compared with No. 9, which transmitted 240.8 B. T. U.

Table I, gives the heat transmitted by each plate in percentages of that transmitted by plates 1 and 9, as before explained. It is necessary to make the comparisons by percentages because the calorimeters used by Professor Carpenter and Mr. Royse do not admit of direct comparisons of the quantity q, it being in one case 278.0 and in the other under other conditions 113.2 B.T.U.

From the data given in Table I, the curves shown were plotted with percentages of heat transmitted as ordinates and days of immersion as abscissae. Cases No. 1 and No. 9 the untreated plates being taken as unity.

TABLE I.

HEAT-TRANSMISSION THROUGH CAST-IRON PLATES.

No. of Plate.	Per cent. heat transmitted.	Days of immersion.	Solution in which immersed.	REMARKS.
I	100.0	0	Untreated.	
X1	81.0	10	10 per cent. nitric.	Curve I.
X2	76.7	20	" " "	
X3	79.0	30	" " "	
1	85.9	10	5 " "	Curve II.
2	71.4	20	" " "	
3	71.6	30	" " "	
6	85.6	10	1 " "	Curve III. Peculiar results, but believed to be accurate.
7	94.0	20	" " "	
8	103.9	30	" " "	
9	100.0	0	Untreated.	
9	87.0	10	10 per cent. nitric.	Curve IV.
11	73.4	20	" " "	
12	77.9	30	" " "	
N	76.8	9	5 " "	Curve V. From Prof. Carpenter's results.
K	70.0	18	" " "	
P	68.5	40	" " "	
E	86.3	9	1 " "	Curve VI. From Prof. Carpenter's results.
B	70.7	18	" " "	
F	68.7	40	" " "	
N	102.0	9	5 " "	Curve VII. After removing rust as explained.
K	91.0	18	" " "	
P	81.8	40	" " "	
E	100.0	9	1 " "	Curve VIII.
B	96.7	18	" " "	
F	90.6	40	" " "	
13	87.9	15	5 per cent. hydrochloric.	Rough. Marked by numbered points on sheet of curves.
1	85.9	15	" " "	Both sides planed.
P	86.8	15	5 per cent. sulphuric.	Rough.
6	85.5	15	" " "	Both sides planed.
7	33.8			Both sides painted with coach varnish.
9	31.7			
11	35.0			
12	32.6			
2	46.2			One side varnished.

In these curves, Fig. 4, the only striking discrepancy is No. III, which is given by the planed plates, in 1 per cent nitric acid. A minimum of heat transmitted is seen to be reached in these cases after about 20 days immersion in a 5 per cent. or 10 per cent. solution, when nitric acid is the attacking agent.

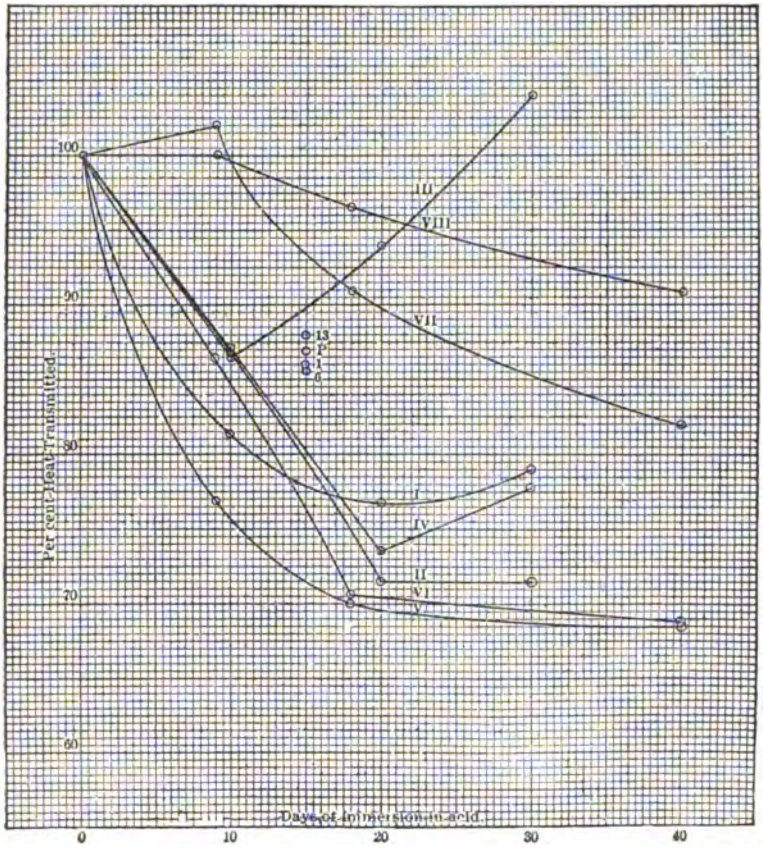

FIG. 4.—HEAT-TRANSMISSION.

With the other two acids nearly the same result was achieved with a 5 per cent. solution and 15 days immersion as with a 5 per cent. nitric acid solution and 10 days immersion.

When both sides of the plates were varnished it is shown that, on an average, but 33 per cent. as much heat was transmitted as when the plate was untreated. The reduction was practically the same with planed as with rough plates, but the varnish adhered much better to the rough plates, and especially if they had been treated before applying the varnish.

It must be borne in mind that the percentages given in Table I are for plates having both sides attacked by the acid. The probable effect with one side only treated may be found as follows:

Assume each surface to present the same resistance to the transfer of heat through it and denote by x the fraction stopped by the first surface, then the second surface will stop the same fraction of what passed through the first, or $x(1-x)$ of the whole. Denote by y the fraction of the heat which passes through the plates, then we have the equation:

$$x+x(1-x)=1-y,,$$
$$(1-x)^2=y,$$
$$\text{or } x=1-\surd y$$

Consider plate No. 2 after being pickled in 5 per cent. nitric acid 20 days: y equals .714, hence $x=1-\surd.714=1-.845=.155$.

Next the side exposed to steam was varnished. It must be noted that the effect of the varnish is not superposed upon that of the acid, but that when it is applied the result is independent of any previous treatment which the surface may have undergone. This is seen in the results obtained from the varnished plates. Also Mr. P. M. Chamberlain found that varnish applied to one side of a plate otherwise untreated reduced the heat transmitted 41.9 per cent., which, as we will see, agrees very closely with the results shown below.

Let the effect of the varnish be to intercept a fraction z of the heat, then for No. 2 we have

$$z+.155(1-z)=1-.4617;$$

hence, $z=.454$, or the single coating of varnish intercepts 45.4 per cent of the heat.

Apply the equation $x=1-\surd y$ to the results obtained from the four plates varnished on both sides, and we have for the reduction of heat transferred, which would occur were one side only varnished and the other left untreated, the following values:

For No.	7,	41.9 per cent.
	9,	43.7
	11,	40.9
	12,	43.0
mean		42.4 per cent.

It is expected that when this treatment is applied to the surfaces bounding the clearance spaces of a steam cylinder, the extent to which the iron, so treated, will store and restore heat, introduced into the engine by the steam, will be diminished at least 40 per cent., and thus some practically useful reduction of the internal wastes will be effected. In the engine the varnish is relied upon to retard this interchange of heat, and the alteration of surface produced by the action of the acid is expected to render the varnish more adhesive and permanent.

These figures are perhaps sufficient to give some idea of the progress made, to date, in the attempt to apply this process to the augmentation of the efficiency of the steam-engine by reduction of its internal wastes; so far as these direct experiments on the variation of conductivity can throw any light on the subject. Incidentally, when investigating the causes of boiler explosions, it was found that simply oiling the surface of the plate where it was slightly rusty reduced the heat-transmitting power ten per cent. It is thus apparently easy to produce sensible improvement in the character of the cylinder-walls in such ways as have been described; that this is actually the result of such treatment as is referred to in the last remark, is shown by the experiments of Hirn and Hallauer, in the introduction of suet into engines, a noticeable gain being thus secured, though at some expense.

But a single set of experiments has been made upon an engine treated in the manner above described. These were performed upon the engine employed in the experiments of Mr. Chamberlain. The method of treatment was that which had been found to give reduction of heat-transmitting power, as already described, of from forty per cent. when acid only was used, to 60 and 70 per cent. when the introduction of the solution of a non-conductor was effected. The engine was first carefully overhauled, valves and pistons were seen to be perfectly tight and the engine otherwise in good order. A very careful trial of the machine was then made and it was found to be in perfect order and the results of the test, which will be presently given, showed that it was in a condition of higher efficiency than at any previous period in its history, so far as the records could be followed. The surfaces of the cylinder and heads, so far as practicable, *i. e.*, where not exposed to the rubbing action of piston and rings, were next treated by Mr. Royse in the manner shown by the previous investigation, as above reported, to be best, and most effective in securing the desired alteration of the surface. The surfaces thus treated were then given a coat of drying oil and allowed one day, only, for its oxidation and the formation of a varnish, the engine being required for other work.* A second trial was then made and the difference in efficiency noted, a difference, as will be seen, presently, of considerable importance, and corresponding very closely with that previously anticipated and computed as probable.

The engine employed was built at the request of the writer as an "experimental engine" for the Sibley College Laboratory of Steam Engineering, with a view to the investigation mainly of questions relating to the action of the plain three-ported slide-value, and was fitted up with a considerable number and variety of valves for this purpose. The steam-cylinder is 6 inches in diameter and the stroke of piston 8 inches. Regulation is effected by a throttling governor and various adjustments, unimportant to this investigation, are provided. The engine is in regular use for purposes of class instruction and the necessity of subordinating this work to the regular work of the college compelled its cessation earlier than would otherwise have been chosen. Following are the logs obtained, as registered on the usual forms of the laboratory for routine testing. The first of these logs is that obtained before, the second that given after the engine had been treated, as already described. The steam was measured by employing a Wheeler surface-condenser; thus, incidentally, converting the engine into a condensing engine. This condenser was that in regular use for the purposes of the laboratory and was tight and efficient.

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*This was not all satisfactory or what was desired, and it is much to be regretted that time did not permit the application of a number of coats, with the complete drying of each. Repeated application, it is probable, would insure the complete saturation of the superficial sponge, and maximum reduction of heat-storing power.

MECHANICAL LABORATORY, SIBLEY COLLEGE, CORNELL UNIVERSITY.

Test of Engine built by Messrs. Payne, Elmira. Ithaca, N. Y., April 13, 1891.

		Rev.	GAUGE READINGS.						TEMPERATURES.							WTS.		HEAD.		CRANK			BRKE		
			POUNDS.			INCHES HG.									CALO.										
Number.	Time.	Speed Indicator.	Boiler.	Steam Pipe.	Steam Chest.	Exhaust.	Condenser.	Barometer.	External Air.	Engine Room.	Condensed Steam.	Exhaust Steam.	Injection Water.	Discharging Water.	Cylinder.	Condensed Steam.	Injection Water.	M. E. P.	I. H. P.	M. E. P.	I. H. P.	I. H. P. Total.	Load.	D. H. P.	Scale of Spring.
1	2:45	200	. .	. .	72.5	22	23^{3}	29.276	. .	77.8	110.4	158	43.6	105.8	263.5	.	.	29.0	3.4	29.2	3.3	.	.	.	.
2	3:00	201	. .	. .	72.0	22	23^{8}		66.2	79.4	111.6	158.5	43.7	108.5	272.5	.	.	29.3	3.2	29.7	3.4	.	.	.	.
3	15	199	. .	. .	70.0	22	22^{3}		. .	80	123.6	161	44.0	110.6	277.0	.	.	29.0	3.4	29.3	3.3	.	.	.	.
4	30	198	. .	. .	72.0	22^{1}	24^{2}		. .	79.4	113.6	157	42.8	83.3	280.0	.	.	30.4	3.5	32.5	3.6	.	.	.	.
5	45	197	. .	. .	70.0	23	24^{1}		. .	80.6	99.0	157	42.9	83.4	280	.	.	29.3	3.4	31.5	3.5	.	.	.	.
6	4:00	203	. .	. .	71.0	22^{2}	24^{2}		66.4	79.6	110.8	157	43.4	98.6	280	.	.	29.7	3.5	30.2	3.4	.	.	.	.
7	15	202	. .	. .	72.0	23	25^{1}		. .	81.5	104.2	155.5	43.0	98.2	281	.	.	31.2	3.7	29.5	3.4	.	.	.	.
8	30	196	. .	. .	72.0	23	24		. .	81.4	104.0	158	42.9	91.4	281	.	.	29.7	3.4	31.2	3.4	.	.	.	.
9	45	202	. .	. .	68.0	23	25^{2}		. .	82.4	97.6	158	42.9	85.6	277	.	.	27.0	3.2	27.6	3.1	.	.	.	.
10	5:00	200	. .	. .	62.0	23^{2}	25^{1}		67.0	83.0	92.2	158.5	43.0	83.1	276	.	.	28.3	3.3	29.0	3.3	.	.	.	.
11	15	180	. .	. .	60.0	22^{2}	23^{2}		. .	82	89.0	157	43.0	85.8	273	.	.	26.5	2.8	36.5	2.7	.	.	.	.
12	30	200	. .	. .	65.0	24	26		. .	81.2	97.8	151.5	43.0	83.2	271	.	.	27.0	3.1	28.5	3.2	.	.	.	.
Mean. .		198.17			68.88	22.73	24.42		66.5	80.7	104.5	157¼	43.19	93.14	276										
Corrected Mean.		198.17			64.80 79.155 abs.			14.355 lbs.	65.°865	79.°923	103.°475	157.°250	42.°758	92.°219	276.°828	714.750	13873.41		3.3152		3.3054	6.6206	57.	4.7100	40

MECHANICAL LABORATORY, SIBLEY COLLEGE, CORNELL UNIVERSITY.

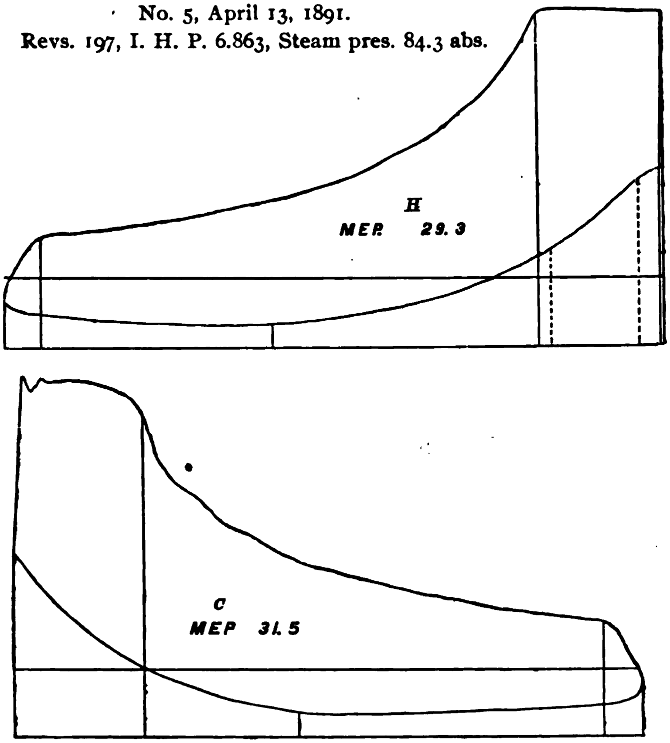
Test of Engine built by Messrs. Payne, Elmira. Ithaca, N. Y., May 1, 1891.

		Rev.	GAUGE READINGS.					TEMPERATURES.								WTS.		HEAD.		CRANK			Brke		
			POUNDS.		INCHES HG.									Calorim.											
Number.	Time.	Speed Indicator.	Per cent Entrained Water.	Steam Chest.	Exhaust.	Condenser.	Barometer.	External Air.	Engine Room.	Condensed Steam.	Exhaust Steam.	Injection Water.	Discharge Water.	Steam Chest.	Cylinder.	Condensed Steam.	Injection Water.	M. E. P.	I. H. P.	M. E. P.	I. H. P.	I. H. P. Total.	Load.	D. H. P.	Scale of Spring.
1	7:15	206	2.66	73	23^{1}	24^{2}	29.132	58	80	100	152	53	99	228	261	.	.	26.5	3.2	29.7	3.5	.	.	.	.
2	30	205	1.50	67	23^{2}	24^{3}		. .	78	103	151	53	85	246	260	.	.	26.0	3.1	30.8	3.5	.	.	.	.
3	45	207	1.70	72	23^{3}	25		. .	80	97	152	52.5	85.5	245	261	.	.	26.4	3.2	27.8	3.3	.	.	.	.
4	8:00	205	2.50	72	23^{3}	25		. .	80	95	151	52.5	88.5	230	261	.	.	26.5	3.2	29.7	3.4	.	.	.	.
5	15	206	2.45	73	23_{3}	25		55	80	95	152	52.5	87.5	232	263	.	.	Indc'r sp'ug slipped.				.	.	.	.
6	30	207	2.70	71	23_{3}^{3}	25		. .	80	95	152	52.5	88	226	261	.	.	24.6	3.0	27.0	3.1	.	.	.	.
7	45	207	2.16	67	23_{3}^{3}	25½		. .	79	95	152	52.5	87	234	260	.	.	26.4	3.2	28.0	3.3	.	.	.	.
8	9:00	207	2.05	67	23_{3}	25½		54	79	95	152	52.5	91	236	260	.	.	26.0	3.1	27.5	3.2	.	.	.	.
9	15	208	2.05	67	23_{3}	25½		. .	79	95	151	52.5	87	236	261	.	.	26.3	3.2	27.0	3.2	.	.	.	.
10	30	207	1.43	68	23_{3}	25½		. .	81	94	150	52.5	87.5	250	261	.	.	27.1	3.3	29.7	3.5	.	.	.	.
11	45	207	1.00	70	23	25½		55	82	93	151	52.5	86.5	258	266	.	.	28.1	3.4	29.7	3.5	.	.	.	.
Mean		206.56	2.01	69.73	23.66			54.5	79.8	96.0	151.15	52.76	88.41												
Corrected Mean.		206.56	X=97.99	69.40	83.700 abs.		14.300 lbs.	54.°40	79.°80	95.°06	151.66	52.065	87.555		261.40	585 lbs.	15229.06 lb		3.17631		3.33507	6.51138	57.	4.90943	40

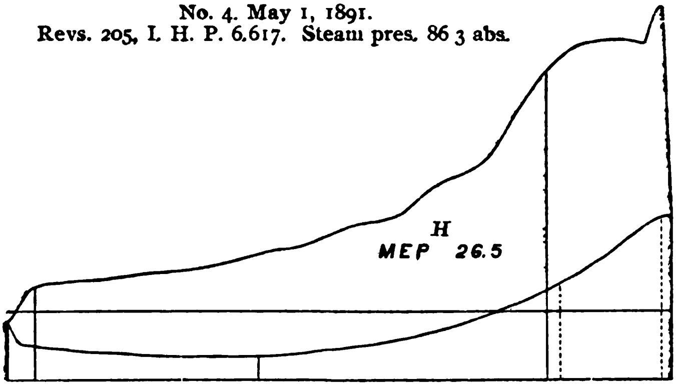
A study of these logs indicates that the engine, for some unexplained reason, probably in consequence of differences in effectiveness of lubrication, ran a trifle faster on the second day than on the first; the engine having meantime, however, been taken apart and re-assembled after a considerable time, required for its treatment. It was very probably slightly altered in the process. This is also indicated by the differences between indicated and dynamometric power. These amounted to 0.9 H. P. the first day and 0.6 the second; the total being highest for the indicated power the first day and for brake-power the second. The engine after being overhauled was thus less subject to friction-losses. These differences, however, are small and probably unimportant. The condenser was carried a little colder the second day and this would tend to correspondingly exaggerate cylinder-condensation. On the whole, the conditions were practically the same, so far as they affect the matter in hand, and the comparison is a fair one.

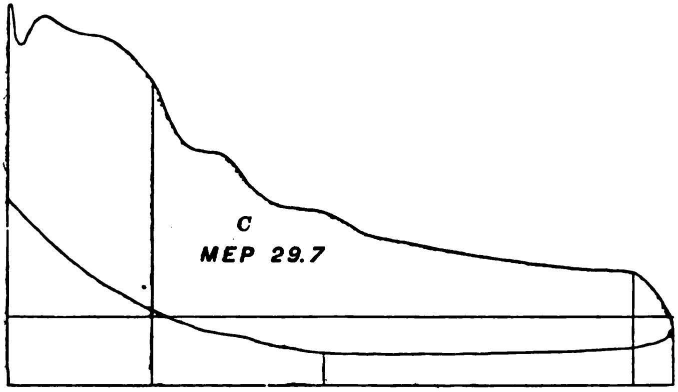
DIAGRAMS FROM PAYNE ENGINES.

No. 5, April 13, 1891.
Revs. 197, I. H. P. 6.863, Steam pres. 84.3 abs.



No. 4. May 1, 1891.
Revs. 205, I. H. P. 6.617. Steam pres. 86 3 abs.





The indicator diagrams taken are substantially alike, on both days, and the following *fac similies* exhibit their form and characteristics. Those taken from the end next the crank are marked *C* and the others *H.* Those taken before treatment are given first; and their slightly smoother form is due, in part at least, to the slightly higher speed at which the engine happened to be moving at the moment. The principle points in the cycle, those at which the observations for Hirn's analysis were taken, are marked on each. For a plain slide valve engine, these diagrams are remarkably good. It will also be noted that the power was well distributed between the two ends of the cylinder; the mean pressures differing but two pounds. The steam-line is good; the expansion-line shows, by its sustained terminal portion, considerable re-evaporation, a proof of initial condensation of considerable amount; the exhaust-period is symmetrically disposed at the two ends and gives a good back-pressure line, terminating with equally symmetrically arranged compression of considerable amount. The slight recurvature at the termination of the compression is well shown and, as the engine was known to be tight, probably measures the condensation of compressed steam, when reaching the point at which the temperature of the steam rose above that of the cylinder walls with which it was at the moment in contact. This is a common, though perhaps seldom noticed feature. The lead of the valve is again seen to be well disposed by the manner in which the steam enters at the termination of the compression-period. As a sample of good setting, this set of diagrams may be taken as admirable.

The investigation, in each case, was made by the system now coming to be familiar to engineers as that of Hirn; though largely due to the patient study of Hallauer and the talent in algebraic representation of Dwelshauvers-Dery. This process consists in the measurement of the quantity of heat-energy brought to the engine by the steam; the quality of the fluid at entrance into the steam-chest; the same quantities and the dynamic energy developed and its distribution, as the engine passes through a complete cycle; the mean, however, being usually taken, for a considerable number of such cycles or revolutions. Thus it becomes possible to determine just what is the method of variation of the proportions of steam and water in the mixture entering the engine and step by step as it passes on into the condenser; to ascertain the quantities of heat converted into work, the amount wasted by external conduction and radiation, and the quantity lost by the process of cylinder-condensation; and the comparison of the power shown by the indicator with that measured by the Prony brake gives the amount of dynamic energy lost by friction in the engine. The whole history of the energy supplied, as it streams through the engine and is distributed, in its various forms of thermal and dynamic, and of useful and wasted, power or energy, is thus given; and, thus tracing it, and its disposition, the characteristic differences of engines, or of the same engine under differing conditions, may be ascertained for the purposes of either scientific or technical investigation. This method was first introduced by its European proposers in the now celebrated work of Hirn and Hallauer, and has since come into use, to a limited extent, in the steam-engineering laboratories of the great technical schools. Mr. J. G. Mair was the first, in regular engineering work, to adopt this system.* His application of the system to trials of pumping engines have furnished some exceptionally valuable data. Where the technical schools are supplied with experimental engines, this method is usually taught as a part of the scheme of instruction of students. The following data were recorded on blanks of the form taken as on the whole most convenient in such instruction in the steam engineering laboratory of Sibley College, Cornell University. The symbols are sufficiently explained by the accompanying memorandum in each line. By following the course of the work as recorded, it is easy to see precisely how the heat and the steam performed the work and, at the same time, were either usefully transformed or wasted, from first to last, from entrance into the engine to their discharge from the condenser.

The first set of figures recorded are the reduced observations from the logs. It has not been thought necessary to present the details of the computations; they may be made from the original data by simple and familiar processes. The two sets of figures which here follow are very similar as it was intended they should be, and the effort to secure similar action of the engine at both trials was evidently very successful.

APPLICATION OF HIRN'S ANALYSIS.

APRIL 13, 1891.—DATA AND RESULTS.

Test of steam engine made by Daniel Royse at Sibley College, Cornell University. Kind of engine, slide valve throttling. Diameter of cylinder, 6.06''. Length stroke, 8''. Diameter piston rod, $1\frac{3}{8}$''. Volume cylinder, crank end, .12921. Volume, head end, .13354. Volume clearance, cu. ft., head, .01744. Clearance in per cent. of stroke, 13.06. Volume clearance, cu. ft., crank, .01616. Clearance in per cent. of stroke, 12.51. Pressure by gauge, steam chest, 64.80. Barometer, 29.276''. Pressure absolute, steam chest, 79.155. Boiling temperature, atmosphere pressure, 210.70. Revolutions per hour, 11890.20. Steam used during run, pounds, 716.4240. Quality of steam in steam pipe, ———. Quality of steam in steam chest, .9941. Quality of steam in compression, 1.0205. Quality of steam in exhaust. .9021. Weight of condensed steam per hour, 259.92. Pounds of wet steam per stroke, head, .0109707; crank, .0109383. Temperature condensed steam, 103.475° = Sg + 32. Temperatures condensing water, cold, 42.758°

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* See Minutes Proceedings Brit. Inst. C. E., Vols LXX and LXXIX; for Hirn and Hallauer's papers, see the Bulletin de la Société industrielle de Mulhouse, 1877–81; also Peabody's Thermodynamics.

=Si+32; hot, 92.219°=Sk+32. Pounds of condensing water, per hour, 5044.878; per stroke, head, .212016; crank, .212274.

SYMBOLS.

To denote different portions of the stroke, the following subscripts are used: Admission (a); expansion (b); exhaust (c); compression (d).

To denote different events of the stroke, the following sub-numbers are used: Cut off (1); release (2); compression, beginning of, (3); admission, beginning of, (0); in exhaust (5). Quality of steam denoted by X.

Cut off, crank end per cent. of stroke, 20.544. Release, crank end, 93.958. Cut off, head end per cent. of stroke, 18.963. Release, head end, 94.971. Compression, crank end per cent. of stroke, 52,341. Pounds of steam per I. H. P., 39.351. Compression, head end per cent. of stroke, 39.770. Pounds of steam per brake H. P., 55.314. I. H. P., head, 3.3152; crank, 3.3054; total, 6.6206. Brake horse power, 4.7100.

MAY 1, 1891.—DATA AND RESULTS.

Test of steam engine made by Daniel Royse at Sibley College, Cornell University. Kind of engine, slide valve, throttling. Diameter cylinder, 6.06″. Length stroke, 8″. Diameter piston rod, $1\frac{3}{16}$″. Volume cylinder, crank end, .12921. Volume, head end, .13354. Volume clearance, cu. ft., head, .01744. Clearance in per cent. of stroke, 13.06. Volume clearance, cu. ft., crank, .01616. Clearance in per cent. of stroke, 12.51. Pressure by gauge, steam chest, 69.40. Barometer, 29.132″. Pressure absolute, steam chest, 83.700. Boiling temperature, atmosphere pressure, 210.62°. Revolutions per hour, 12393.60. Steam used during run, pounds, 586.7041.. Quality of steam in steam pipe, ———. Qualtiy of steam in steam chest, .9799. Quality of steam in compression, 1.020. Quality of steam in exhaust, .86209. Weight of condensed steam per hour, 234.000. Pounds of wet steam per stroke, head, .0091623; crank, .0097722. Temperatures condensed steam, 95.060°=Sg+32. Temperatures condensing water, cold, 52.065°=Si+32; hot, 87.755°=Sk+32. Pounds of condensing water, per hour, 6091.62; per stroke, head, .237114; crank,.254396.

SYMBOLS.

To denote different portions of the stroke, the following subscripts are used: Admission (a); expansion (b); exhaust (c); compression (d).

To denote different events of the stroke, the following sub-numbers are used: Cut off (1); release (2); compression, beginning of, (3); admission, beginning of, (0); in exhaust (5). Quality of steam denoted by X.

Cut off, crank end per cent. of stroke, 21.843. Release, crank end, 94.977. Cut off, head end per cent. of stroke, 19.143. Release, head end, 95.715. Compression, crank end per cent. of stroke, 52.153. Pounds of steam per I. H. P., 36.0431. Compression, head end per cent. of stroke, 37.714. Pounds of steam per brake H. P., 47.8022. I. H. P., head 3.17631; crank, 3 33507; total, 6.51138. Brake horse power, 4.9 943.

DATA AND RESULTS PER 100 STROKES.

			APRIL 13.		MAY 1.	
QUANTITIES.	Symbol.	FORMULAE.	HEAD.	CRANK.	HEAD.	CRANK.
Steam used by calorimeter, lbs.,	M_x		.00490		.00545	
Steam from boiler, lbs.,	M		1.09707	1.09383	.91623	.97722
Steam in clearance, lbs.,	M_o	$100 \frac{V_c + V_o}{C_o X_o}$	.16458	.14414	.14346	.14540
Steam, total, lbs.,	$M + M_o$		1.26165	1.23797	1.05969	1.12262
Heat of condensed steam,	K'	$(M - M_x) S_g$	78.0629	78.1815	57.4338	61.6235
Condensing water, lbs.,	G		21.2016	21.2274	23.7114	25.4396
Heat given to condensing water,	K	$G (S_k - S_i)$	1048.6523	1049.9284	844.5176	902.8514
Heat supplied to engine,	Q	$M (X L + S)$	1285.2743	1281.4785	1062.8957	1133.6487
Sensible heat at admission,	H	$M_o S_o$	37.9982	33.4579	32.5093	33.8271
Internal " "	H_o'	$100 \frac{V_c + V_o}{C_o} I_o$	143.5501	125.5798	125.5173	126.5534
Sensible heat at cut-off,	H_1	$(M + M_o) S_1$	338.3488	328.2161	281.9831	295.4915
Internal " "	H_1'	$100 \frac{V_c + V_1}{C_1} I_1$	545.5026	528.1695	534.8858	531.3785
Sensible heat at release,	H_2	$(M + M_o) S_2$	254.4084	254.0300	206.1891	227.8784
Internal " "	H_2'	$100 \frac{V_c + V_2}{C_2} I_1$	701.1183	706.5868	626.7889	688.2081
Sensible heat, begin'g of compression,	H_3	$(M_o + M_x) S_3$	21.3924	19.0826	19.5355	20.8868
Internal " " "	H_3'	$100 \frac{V_c + V_3}{C_3} I_3$	113.9140	103.6313	131.0014	131.9348
Cylinder loss during admission,	Q_a	$Q + H_o + H_o' - H_1 - H_1' - \frac{W_a}{778}$	551.1356	549.8245	370.6544	430.0416
" " " expansion,	Q_b	$H_2 \div H_1' - H_2 - H_2' - \frac{W_b}{778}$	−135.8615	−163.1786	−75.1285	−147.0454
" " " exhaust,	Q_c	$H_2 + H_2' - H_3 - H_3' - K - K' - \frac{W_c}{778}$	−303.3649	−285.3828	−214.9133	−193.6765
" " " compression,	Q_d	$H_3 + H_3' - H_o - H_o' - H_x - H_x' - \frac{W_d}{778}$	−29.7279	−18.6036	9.0961	11.4304
Heat discharged, and work,	B	$K + K' + H_x + H_x' + \frac{778}{W}$	1203.0930	1198.8789	973.1920	1032.8986
Loss,	D	$Q - B$	82.1813	82.6596	89.7087	100.7501
Loss,	D'	$Q_a + Q_b + Q_c + Q_d$	82.1813	82.6595	89.7087	100.7501

SUMMARY AND RESULTS.

QUANTITIES.	Symbols.	FORMULAE.		APRIL 13. HEAD.	APRIL 13. CRANK.	MAY 1. HEAD.	MAY 1. CRANK.
Quality of steam entering, ...	X	Per calorimeter,	per cent.	99.41	99.41	97.99	97.99
Quality of steam at cut off, ...	X_1	$100\frac{V_c+V_1}{(M+M_0)\,C_1}$	"	52.34	51.50	60.986	57.045
Quality of steam at release, ...	X_2	$100\frac{V_c+V_2}{(M+M_0)\,C_2}$	"	63.34	65.26	66.048	69.953
Quality of steam at compression, ...	X_3	$100\frac{V_c+V_3}{(M_0+M_x)C_3}$	"	71.75	77.16	94.318	98.338
Quality of steam at admission, ...	X_0	$100\frac{V_c+V_c}{M_0\,C_0}$	"	102.05	102.05	102.00	102.00
Quality of steam at admission, ...	X_0	Per calorimeter,	"	102.05	102.05	102.00	102.00
Quality of steam in exhaust, ...	X_5	$\left(\frac{K+K'}{M-M_x}-S_5\right)\div L_5$	"	90.214	90.195	86.328	85.996
Heat lost, admission, ...	a	$Q_a\div Q$	"	42.881	42.905	34.872	37.934
Heat restored, expansion, ...	b	$Q_b\div Q$	"	10.571	12.733	7.068	12.962
Heat rejected, exhaust, ...	c	$Q_c\div Q$	"	23.603	22.270	20.220	17.084
Heat lost, compression, ...	d	$Q_d\div Q$	"	—2.313	—1.452	.856	1.008
Heat utilized, work, ...	w	$\frac{W}{778}\div Q$	"	5.518	5.518	6.136	6.036
Heat lost, radiation, ...	r	$D\div Q$	"	6.394	6.450	8.440	8.887
Ratio, radiation to work, ...		$r\div w$		1.1588	1.1689	1.3755	1.4723
Ratio, cylinder condensation to work, ...		$a\div w$		7.7711	7.7757	5.6318	6.2843
Thermodynamic efficiency, ...	E	$(t-t_3)\div(461+t)$	per cent.	19.921	19.031	19.715	19.546
Actual efficiency, ...	E_1	$\frac{W}{778}\div Q$	"	5.518	5.518	6 136	6.036
Efficiency compared with ideal, ...	E′	$E_1\div E$	"	27.67	28.99	31.12	36.48

The summary of data and the results, shown in the second of these last tables, constitute a most interesting study apart from their relation to the problem here sought to be solved by their use. The whole table is one of percentages of the total heat, steam and energy entering the engine from the boiler. It is seen that on both occasions, this steam was practically dry, the water constituting but one and a half to two per cent. of the whole mass. At the point of cut-off, however, this figure becomes immensely altered and we find from forty to nearly fifty per cent. condensed at that point, a quantity measuring the waste by "cylinder-condensation," occurring as the steam enters the comparatively cold engine, and the heat thus surrendered to the metal supplying the place to that given out by the cylinder-walls during the immediately preceding period of exposure to the cooling influence of expansion, exhaust and liquefaction in the condenser. At the point of release, a portion of this heat has been restored to the steam, as it expanded to lower pressures and temperatures, becoming, in turn, cooler than the adjacent cylinder walls. This heat aids, to a limited extent, the transformation of heat into work; but, evidently, not to the same extent as that which was transformed from the maximum initial temperature. Ten to fifteen per cent. is seen to have been thus returned by the metal of the cylinder before the exhaust-valve opens and release begins.

At the commencement of the compression we note that the "quality" of the steam has risen, by the re-evaporation or separation of the water contained in the charge, to about 75 per cent., in the first trial, and to 95 in the second; and here we begin to see the effect of our treatment of the interior surfaces of the cylinder. The variations between head and crank end and possibly a part of the greater differences between the same ends on the two days may probably be largely due to the difference in the quantities of water collected in various hollows and in the drops adhering to the inner surfaces of the engine. The carbonized and varnished surfaces would evidently not permit as ready adherence as the untreated metal. The quality of this same steam, however, after compression is completed, is raised by absorption of the heat of compression, and perhaps in part by absorption from the cylinder-walls to 102; which means some superheating. This unlooked for result is given both by the measurements of the diagram, and also by the use of a calorimeter, ingeniously contrived to sample and test the steam at any desired point in the stroke. Both methods give precisely the same figure. The steam passing into the condenser is seen to contain ten per cent.

moisture before and about fourteen after treatment, a result which is not easily explained, but possibly may indicate that the engine, in the first case, sent out all its steam as part of a comparatively heterogeneous mixture, while in the second trial, it may have carried all its water in suspension and uniformly.

The heat utilized by transformation into dynamic energy for the performance of work, as shown by the indicator, was 5.5 per cent. the first day, and 6 per cent. the second ; showing a gain of nearly 10 per cent. in efficiency of engine, and quantity of heat and steam, and fuel consumed. The computed thermodynamic efficiency of the perfect engine working within the same extreme limits of temperature, would have been 20 per cent. ; and the real engine thus gave but 28 per cent. of the ideal figure, the first day, as untreated, and about 35 per cent., the second day, after treatment. The economic result of the application of this progress, in this instance, is thus seen to be a gain of about 10 per cent. Had the time for complete application been allowed, and the surfaces been given its full benefit, increasing their useful action from the observed 4 per cent. to 70, it is presumed that the gain would have been correspondingly greater. Just how far this increased advantage is attainable must be determined by further investigation.

The figures as obtained by the tests above described, on a basis of 2.25 pounds of steam for the ideal engine at efficiency unity, correspond to an expenditure of 40 and of 36 pounds of steam per horse-power per hour, for the two cases respectfully, engine as originally operated and as treated, or to about 4½ and 4 pounds of coal with economical evaporation. This corresponds to a saving of about three-quarters of a ton of coal per annum per horse-power, or say three dollars a year, per horse-power, the interest, at six per cent., of fifty dollars per horse-power ; while the cost of treatment might average, time included, one dollar, on small engines, and a few cents on very large powers. It still remains to be determined, by experiment and by extended experience, to what extent this scheme may be made more effective, and whether it is likely to be satisfactorily permanent. Should it require renewal, like the cleaning of boilers it will become a question to be settled in every case how thoroughly and how frequently it will pay to take that trouble and go to that expense. The economical aspect of the problem will very likely require much careful observation and experimentation for settlement. All that can be said at present is that it is undoubtedly the one direction in which engineers are to look, in future, for great or rapid improvement in steam-engine economy and enough has been learned to show that it is well worth while to prosecute this investigation with the utmost diligence and care.

THE APPLICATION OF ELECTRICITY TO THE MEASUREMENT OF TIME.*

" Men count Time's footsteps, but Nature his busy taskmaster pauses not to heed them."

BY A. E. KENNELLY.

There is perhaps no department of human knowledge and perception in which the limitation of our senses is more clearly defined than in that which relates to the province of time. The only means we have at present of measuring it is by taking the periodic motion of some one body as a standard by which to classify and compare all the movements and sequence of events. Our present standard body is the earth, whose revolutions about its axis are the periodic motions that constitute our standard of reference. The times in which Nature's operations are performed are often all too great or far too brief to be capable of our direct appreciation in sense. Each second of time sees 500,000,000,000,000 ether waves each completing its time integrals of energy and speed and in one second each air-molecule out of the myriads that encompass us finds time to make some 5,000,000,000 collisions among its neighbors.

Charles Wheatstone's method has shown itself capable of rendering appreciable the very shortest intervals of time that we have yet been able to manifest, intervals representing the $\frac{1}{500000000}$th of one second, which have been reached by the periods of oscillatory condenser discharges following the method of Hertz first outlined by Sir W. Thomson. On this principle Professor Trowbridge has recently made observations tending to show that iron magnetizes and evidences effects ot magnetization in $\frac{1}{500000}$th of one second.

The next intervals in order of brevity at our experimental control are those obtained with the continuous discharges of condensers, that is to say discharges taking place through circuits whose electrostatic time constant (k r) is not less than four times the electromagnetic (l r). Such methods apply to the determination of the duration of impact between metallic substances. The time during which a rebounding hammer rests in contact with an anvil is about the $\frac{1}{1000000}$th of a second, and by calculating in this way the interval of impact between suspended sheres, an independent method is secured for the determination of Young's modulus.

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* Synopsis of an address to the students of Sibley College, Cornell University, February 5, 1892.

These impact durations are nearly independent of the velocity and in the experiments that have been described were found to vary directly with the diameter of the sphere.

Next in order of time come intervals from 10^{-4} seconds up to days and years, all of which come within the scope of chronoscopes, chronographs, or chronometers, Such intervals as these have the most important practical bearing and utility. Nerve sensation is stated to travel about 70 feet per second, and nerve stimuli can only succeed each other at certain rates. The swiftest telegrapher on record can make keyed impulses at the average rate of 19 per second for 300 continuous seconds, while Czereny's finger exercises more modestly demand 12.3 finger impulses per second for a time whose full duration is left to the mature deliberation of the embryo Paderewiski. Our physical records of speeds on the race course do not reject first decimals of a second. The practical measurement of solar time to this order of accuracy generally applies to the determination of terrestial longitude, and this is carried to so high a degree of refinement between fixed observatories, that with the aid of electric telegraphy the longitude in distance is frequently established to within a few yards of probable error. Electricity not only enables this degree of accuracy to be approached by conveying signals, but also regulates time keepers such as large chronographs or equatorials.

The principle of electrical driving and of securing the most perfect adjustment of acceleration is well instanced in the Edison Phonograph, an instrument in which the slightest deviation from uniform angular velocity would greatly interfere with the faithful reproduction of music and speech. Its sensitiveness is so great that if the reproducer's spherule be passed over the surface of a polished lens, which is really a surface burnished with very fine scratches imperceptible to the unaided eye, grating sounds are heard through the ear tubes, which sounds are not usually heard when the same operation is performed on an uneven but smooth surface of fracture in glass,—a peculiar evidence of inferiority of artifice to the void of art, that is reassuring by its very rarity.

Turning onwards to long intervals of time electricity comes to the rescue in the breach of hopelessness by methods somewhat more indirect. It has been shown that assuming no discontinuity has occurred in the existing order of things since the first general formation of a solid crust on the molten surface of this planet in the days of its fervid youth, the date of that era is calculable to at least a fair degree of approximation from a knowledge of the earth's initial temperature, and the thermal conductivity of its constituents combined with the measurement of its existing temperatures at different depths. The age of the world's crust, as estimated in this way by Sir W. Thomson, is 98,000,000 years. The limits of this estimate are very wide, being from 20,000,000 to 400,000,000 according to the different values that may be accorded to the variables in the equations without exceeding the limits of reasonable possibility. These limits would be capable of considerable restriction if the temperatures of the rocks at different depths below the surface could be more generally and fully investigated than heretofore and there is perhaps no method so readily capable of yielding this information than that of measuring temperatures by their influence upon the electrical conductivity of metals. Insulated coils of wire with leads communicating above the surface have only to be buried moisture proof in vertically bored shafts to show by their resistance at any moment their contemporaneous temperature, within a sufficiently narrow limit of error.

The swiftest bodies within what we call terrestial regions, are the fiery meteors which in their leap to the tranquil lap of earth are said to sometimes indicate a velocity of forty-five miles per second. The swiftest body in the known universe is the star Groombridge 1830, whose component velocity in the plane normal to its line of sight is stated at about 200 miles per second, and which may be as much greater as the secant of the unknown angle its direction makes with its geocentric radius vector, exceeds unity. Kepler originated the conception that there might be stars so distant that since their birth in ages past their light had not yet had time even at its own enormous rate of 186,000 miles per second to reach our earth. Associated with these enormous speeds and distances our little unit span of the earth's distance from the sun recedes into insignificance as a mote tossed on the unmindful surface of the sea. Yet when annual parallax is helpless to measure these distances, and times of flight, the light of these stars carries in its undulations the records of its first impulse and reveals in the spectrum the star speed in the line of light at that possibly remote era when the ray waves bade their birth place farewell. The long distance measurements of the universe are determined in light-spans and are dependent upon our knowledge of light velocity. It would seem that the sun's distance from the earth may be ultimately known to a higher degree of accuracy by the speed of light than by the methods of transits and occultations. It so happens that the speed of light is probably capable of more careful and exact measurement by purely electrical methods than has yet been possible from any observations on light itself, and there is reason to believe that the physical ratio between any electrical quantity as measured in terms of electrostatic or electromagnetic force contains this light speed implicitly. A number of measurements of this ratio have already been made by different observers in various ways and the discrepancies between the best results are yearly diminishing.

It is Mr. Edison's intention to carry out an experiment he has long held in view, of endeavoring to find a direct electro-magnetic solar effect upon the surface of the earth. This is of course independent of the electromagnet theory of light. His object is to surround a hill of iron ore having an appreciable magnetic permeability, with a number of insulated wires, thus realizing a test magnet surrounded by a coil upon a very large scale. The marked coincidence between the sunspot period and those of magnetic disturbances all over the world render the thought hopeful that a telephone or other electrical apparatus introduced into the circuit enlacing the iron hill might perhaps reveal some evidences of electrical disturbance coincident with magnetic observatory variations and traceable directly to solar influence. If this could be accomplished another avenue of observation might be opened by determining the time occupied by magnetic impulses to reach us from the sun compared with the speed of light.

The assistance of electricity in the determinations of time may thus be counted on directly or indirectly from periods of millionths up to those of billions of seconds. Within this vast scope only a narrow intermediate range affects directly our practical and utilitarian requirements, but it is within the limits of possibility that the applications of electrical measurements to the most minute durations in which molecules count their evolutions, may by aiding in the ultimate discovery of the nature of matter bestow advances upon our race that shall eclipse all those now possessed in existing practical electrical applications to the measurement of time.

NEW PUBLICATIONS.

MANUAL OF THE STEAM ENGINE. Part II. Design, Construction, and Operation. By Robert H. Thurston, A.M., LL.D., Dr. Eng'g.

This volume, which has been issued since the publication of the last number of THE CRANK, constitutes the second and final volume of Dr. Thurston's great work on the Steam Engine. In size and typographical appearance it resembles very much the first volume, but in some respects the typography is even more elegant and finished.

The merit of the work will commend itself to all students who have occasion to use it, and for their convenience a brief statement is made of the contents. The work is devoted to the design, construction, and operation of the engine, and it is without doubt the most complete treatise in a single volume, to be found on the above subjects; it is written from the standpoint of the student, and the principles of construction are made in each case as prominent as the practical methods employed. The topics treated are as follows:—

Five hundred and forty-two pages are devoted to the subject of engine design, in the various chapters as follows: I. General principles to govern the selection of a type of engine, condensing, non-condensing, compound or simple. Proportions of the various parts, and design of engines for special purposes. The design of the complete plant is also considered, including proportions for chimneys and design of the boiler. II. A special chapter devoted to valve gearing and steam distribution, in which are given the valve diagrams, general classification of valves, and a detailed description of nearly every valve in use. III. Regulation of the engine, external variations of energy and power, the effect of inertia, use of the fly-wheel and governor. In this connection is given the most complete discussion of the fly-wheel governor yet published, and detailed description of various governors, and methods to be employed in their design and in balancing an engine. IV. Construction and erection, in which the various precautions to be observed in the use of materials in the construction and erection of the engine are fully set forth.

A chapter is devoted to operation, care and management of engines, another to engine and boiler trials. The work also devotes a chapter to specifications and contracts, and one to finance. The last two chapters are especially worthy of careful study, as they form about the only available literature on the subject. The method of drawing specifications and contracts is clearly and fully explained, and will be almost invaluable to the young practicing engineer. The subject of "finance" treats on broad grounds those questions of economy and revenue so important to the owners and investors in the plant; it is without doubt the first time this important problem has been adequately treated.

As compared with the first volume, this is decidedly the more valuable to the practicing engineer, who is seeking for methods rather than theories, and it will form a valuable reference book in the designing room. The two volumes together treat the whole subject completely both from the theoretical and practical standpoint, and in this respect constitute the most perfect treatise on the steam engine ever yet produced.

PROCEEDINGS OF THE NAVAL INSTITUTE. Vol. XVII, 1891.

The last quarterly volume contains articles of well sustained ability on the usual range of topics relating to naval matters.

One topic of great importance in connection with the upbuilding of our Navy is the proper organization and training of those who are to man these new ships. The prize essayist of the year was Ensign A. P. Niblack, whose essay treated of these matters. The author recognizes the fact that new ships and guns, powerful machinery and efficient officers, are not alone enough to constitute an efficient ship. The sailor and fireman, the mechanic and gun-captain, are also recognized as all important elements in a ship's efficiency. The essay is a study of methods looking toward the improvement of the crew in two ways. First, by improving their actual surroundings in many ways, and second, by such improved surroundings and better pay, the gradual elevation of the character of men drawn into the service. Various forms of drill and exercise suited to the changed conditions of naval warfare are also suggested and discussed.

On ordnance and gunnery there are several articles of both scientific and practical value. Among the former is an extended article on modern explosives and ordnance material by Stephen H Emmens. In this article an excellent idea is given of some of the recent problems with which modern ordnance is called upon to deal, as well as of the special ways and means by which such studies are carried out. An interesting form of experimental ammunition cart for shore service is described by Lieut. W. W. Kimball. This cart has two cases and two wheels and may be drawn by a horse or mule between shafts, or it may be separated, and each box with one wheel may be manipulated by two men. Provision is also made for its use as a stretcher for conveying wounded from the field.

On naval architecture there is an interesting article on stability of ships by Naval Constructor D. W. Taylor, U. S. N. The method proposed by the author is a modification of older methods with a combination of some of the good points of English and French writers on the subject. The article is accompanied by tables specially computed to aid in the calculation of stability by this method.

An article of much interest is presented by E. E. Hayden, U. S. N., on the Samoan Hurricane of March, 1889. The author has made a specialty of marine meteorology and gives the results of his studies on this storm, one of the most terrific ever known.

On mechanical engineering topics there is from the pen of Dr. R. H. Thurston a suggestive and interesting paper on the final improvement of the steam engine, which appears elsewhere in the present number of THE CRANK.

THE CRANK.

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WHAT JOHN BULL EXPECTS FROM HIS ENGINEER STUDENTS.

The methods of the professional schools and departments of Cornell seem to be in vogue in England, in the selection of officers for the engineer-corps of the navy. We find in *The Marine Engineer* of Feb. 1, the following: "Not a little sensation has been created among the engineer students, at Devonport, over the action of the Admiralty in dismissing three of their number from the college, and in reprimanding some fourteen or fifteen others, on account of unfavorable reports forwarded to headquarters regarding the progress made in their studies, and the capacity shown for the profession of engineers in the navy." The course of study given them is similar to that in Sibley College, Cornell University, including scientific instruction in the college and practical training in the workshop. The editor continues: "The Admiralty have therefore the right, in the interests of the Naval service and of the taxpayer, to demand something more than vacuity in return for the public money expended. Diligence, with a certain amount of sagacity, is essential in the engineering profession; but these qualities were evidently lacking in the youths concerned." . . . . "Sentiment must go to the wall seeing that it is engineers who must emanate from the college, not ghosts of the same." In the same issue of this journal, Admiral Symonds, R. N., publishes a long and very despondent communication "On the truly perilous state of Great Britain, should War occur between France and Ourselves," in which he gives as unhappy an account of Great Britain, in this matter, as could be given of the United States Navy by its own officers as affecting a war with Chili.

A CHICAGO INSTITUTE OF TECHNOLOGY.

An interesting and significant paper was read before the Chicago Electric Club, recently, by Mr. F. W. Parker, urging the establishment of a great technical school at that metropolis. Its author shows that no place in the world offers such facilities or exhibits a greater need of schools of engineering and the useful arts. After referring to the beginning now made, including the Manual Training Schools, he says: "Rival schools annually discharge their multitudes into professions of law, medicine, and the like—which I may perhaps be excused for calling the *destructive* professions—while not a school gives us a graduate of any of the *constructive* professions of engineering." He concludes that Chicago, "this great city of a million and a quarter of inhabitants, itself the proudest product of modern engineering, must have absolutely the best technological institution in the world," with the best laboratories and museums, "such as only a mighty nation of inventors, manufacturers and engineers, can produce.

SUCCESS ASSURED FOR THE NEW SCHOOL OF MARINE ENGINEERING.

The Department of Marine Engineering and Naval Architecture, the "Graduate School of Marine Engineering of Sibley College," as it has been officially called, has already made a very good start and has a considerable number of both graduate and undergraduate students enrolled; although nothing has, as yet, been done in the way of publishing the fact that it is organized and ready for business. This will be done during the interval between now and the coming fall term. The circulars are in process of preparation, and will be ready for distribution soon. It seems to have excited some interest elsewhere, and we observe that it is proposed to establish a similar school at the Johns Hopkins University. The success of this and similar schools at Cornell is largely due to the eminently practical spirit which pervades the technical departments here, and to the presence in the faculty of experienced men of business and affairs competent, not only to give instruction in the pure theory of the technical and professional branches in which they are interested, but also to discern the most important and most desirable applications of their theoretical knowledge, and to temper their rigid theories with the expediencies of practice and finance. It may well be doubted whether any college in which this spirit is not present to modify the work of pure science, can successfully offer instruction in professional and constructive work. Elaborate and imposing discussions of wave-motions cannot be made to take the place of instruction in the computations of displacements, "the powering" of ships, the laying down of lines, or the working of iron.

COLLEGE ETHICS.

Never value anything as profitable to thyself which shall compel thee to lose thy self-respect, to break thy promises, to hate any man, to suspect, to curse, to act the hypocrite, to desire anything which needs walls and curtains.—*Antoninus.*

An honest desire to excel is always laudable, and to create such a desire in university work, prizes are often offered. In Sibley College the conscientious student who can combine ambition, application and brain, hopes to see his name among the winners of the Sibley prizes and, as a final inducement, an election to the Sigma Xi is offered those who have excelled in their work.

The prize system, as a system, has its faults and its benefits, and should produce fewer cases of "leg-pulling" in a University of this sort than in a smaller college. Here a man can become as interested as he wishes in his work, and it is an insult to a Professor to suspect that favor can be obtained in any other way. We have here a miniature world. Every man has his own object and interests and by the time he becomes a Senior he should have a pretty clearly defined knowledge of what he is going to do after he leaves college, and his efforts should be spent in better preparing himself for the fight to come.

An argument which has been urged against college graduates by practical business men, is that they desire to supercede the superintendent before a month has passed, and that within six months they can instruct the president of the company in whose employ they are. A business man who has been unfortunate enough to have met one of these phenomena, and who condemns all college graduates *à priori*, will not easily be convinced that there are many earnest men who graduate from Cornell, with right estimates of themselves, and who would gladly begin at the bottom and work up by the use and not the abuse of their education.

It is a difficult thing for a Professor to teach a man to be a gentleman—by a gentleman we mean a fellow who is modest, self-reliant, ambitious, and honest with himself as well as his fellow students. An instance came to our attention not long since of a Senior who has always stood high in his classes, who informed a Professor that another Senior who was detailed to work with him, was not doing his share of the work, and that he, the smart Senior, was tired of allowing another man to copy his results. The result was a "condition" for the unfortunate man, unfortunate because he should meet such a combination of conceit and self-assurance in a fellow student. No matter how true the charge may have been, such actions should be condemned by every student who has the instincts of a gentleman, and the informer should bear in mind the fact that a reputation built on nothing more substantial than information furnished concerning others short comings is an exceedingly frail one, and will stand very few, if any, of the hard knocks that are sure to come after graduation.

DR. THOMAS STERRY HUNT.

Dr. Thomas Sterry Hunt, one of the leading chemists, geologists and mining engineers of the country, died in New York February 11. Dr. Hunt was born in Norwich, Conn., September 5, 1826. He was educated for the medical profession, but his love for chemistry and mineralogy led him to become a student, and he was soon assistant to Professor Benjamin Silliman, Sr., in Yale College.

In 1847 he was appointed chemist and mineralogist to the Geological Survey of Canada, which position he held until he resigned it in 1872. He made the first systematic attempt to subdivide and classify geologically the stratiform crystaline rocks. To him science is indebted for the distinctions and the designations of Laurentian, Norian, Huronian, Montalban, Taconian and Keweenian. He was one of the organizers of the Laval University, at Quebec, and was professor of chemistry there from

1856 to 1862. For four years he was lecturer in McGill University, Montreal, and was professor of geology at the Massachusetts Institute of Technology from 1872 to 1878. A fellow of the Royal Society of London since 1859, he was a member of a large number of other societies, both American and foreign.

He was a member of the National Academy of Sciences; had been president of the American Association for the Advancement of Science, and of the American Institute of Mining Engineers, and was twice president of the American Chemical Society. He was one of the founders, and the first president by election ot the Royal Society of Canada. One of the organizers of the International Geological Congress, he was its first secretary, and was a vice-president at the congresses of Paris, 1878; Bologna, 1881, and London, 1888. Dr. Hunt was a member of the international juries at Paris in 1855 and 1867, and at the Centennial Exhibition in 1876. He was an officer of the French order of the Legion of Honor, and an officer of the Italian order of St. Mauritius and St. Lazarus. In 1878 he retired from public professional life. Dr. Hunt was the author of many works, among which are "A New Basis for Chemistry," "Systematic Mineralogy," and "Chemical and Geological Essays."

PERSONALS.

'88.

G. W. Bissell and G. L. Teeple were visiting friends in Ithaca recently.

'90.

Harry T. Shick will be married at Reading, Pa., Thursday evening, Feb. 25.

W. Nelson Smith is with the Chicago Arc Light and Power Company at Chicago, Ill.

'91.

J. J. Herrick is in the N. Y. Central shops at Albany.

O. S. Lyford is with the Chicago Edison Company at Chicago, Ill.

E. E. Fisher is with the Field Engineering Company, at Paterson, N. Y.

C. M. White is with the Long Distance Telephone Company at New York City.

F. Land is with an Electrical Railway Construction Company, of New York City.

L. T. Gibbs is with the Milwaukee Street Railway Company at Milwaukee, Wis.

R. E. Danforth is putting in an electric railway for the Field Engineering Co., at Buffalo, N. Y.

G. F. Myers of Pittsburgh, R. G., was married on Jan. 14, at Worcester, Mass., to Miss Grace Whiting of Boston.

Arthur Field, captain of last year's baseball team, is with Field, Benedict and Company, woolen importers of Chicago, Ill.

L. A. Osborne is with the United States Electric Lighting Company, of Newark, N. J. At present he is superintending a new plant at the Holland House, New York City.

Jos. L. Hall, editor-in-chief of THE CRANK during last year, is now with the Field Engineering Company and has been sent to Trenton, N. J., to assist in putting in an electric road in place of the horse road already in operation.

Lieut. Frank A. Barton, U. S. A., last year's colonel at Cornell, has joined his regiment in Arizona from Fort Leavenworth, Kansas. Lieut. Barton's Company, Co. "B," 24th Infantry, is at present on outpost duty in the Apache district at Fort Thomas.

'92.

W. S. Lovell, is with the Westinghouse company, at Pittsburgh, Pa.

Jas. Tracy is now with the Toledo Natural Gas Company, at Toledo, Ohio.

E. Everett is in the drafting office of the Pennsylvania R. R., at Williamsport, Pa.

C. J. Canal, who has been visiting at his home in Cucuta, U. S. of Columbia, since July, returned last week to resume his studies.

'93.

C. E. Warner is with the Edison Electric Company, at New Westminster, British Columbia.

'94.

W. L. Elkins is purchasing agent of the Pittsburgh Traction Cable Co., at Pittsburgh, Pa.

CURRENT EVENTS.

Military Hop, Feb. 26.

Winter Meets on Feb. 20 and March 4.

The prospect of a fine baseball nine is excellent.

Burrows, '92, has been elected captain of the nine.

A University lacrosse club was recently organized.

F. M. Black, '92, has been elected baseball manager.

Freshman Banquet on Feb. 26, at Clinton Hall, Ithaca.

The *Era* has started subscription lists for the crew fund.

Gen. A. C. Barnes has given $250 to the Barnes Hall Library.

The Senior class has selected Mr. Evans as class photographer.

The Glee Club will give a concert at Barnes Hall on March 1.

Harry Sumner, the famous Oberlin College pitcher, has entered Cornell.

Theta Xi, the engineering fraternity, has recently established a chapter at Cornell.

The baseball games scheduled to be played with University of Michigan are declared off.

Bulletins can be obtained of Dr. Thurston, of the Sibley College Inspection Tours for the spring vacation.

Captain R. W. Hunt, of Chicago, will deliver a Sibley College lecture, on Feb. 26, on "Wire Rod Rolling."

The new Allis triple expansion engine for the mechanical department is in place and all connections have been made.

Mr. Wm. Caldwell, instructor in the Sage School of Philosophy, has accepted an instructorship in Economics at Chicago University.

The number of candidates for the Freshman crew has been reduced by Coach Courtney to sixteen. Fourteen men are training for the 'Varsity crew.

The frontispiece of *Cassier's Magazine*, for January, is an excellent photogravure of Professor R. C. Carpenter. A biographical sketch is also given.

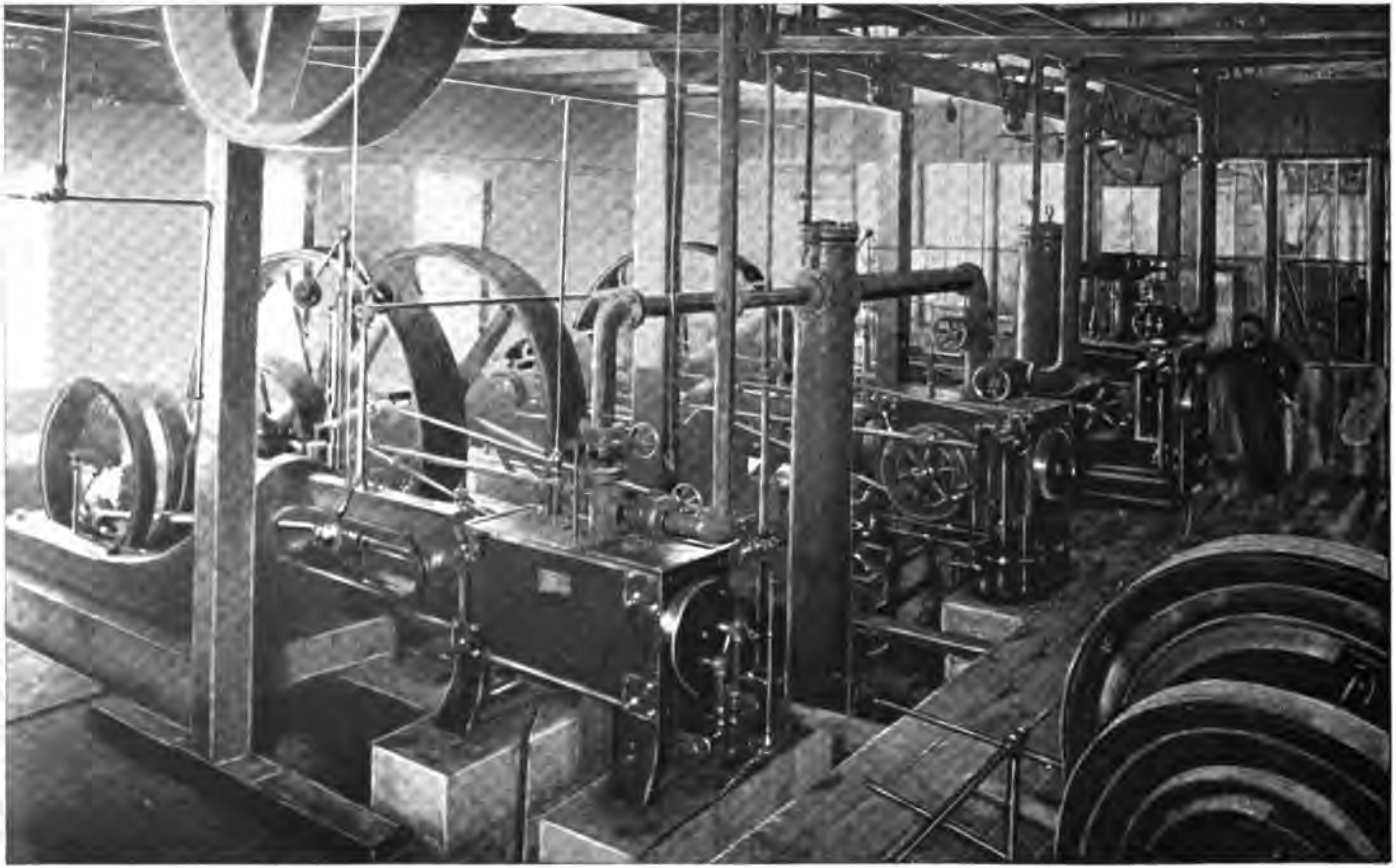
The Junior Ball, Sophomore Cotillion, and the Glee, Banjo, and Mandolin Clubs' concert, were the most successful and brilliant series of social events ever given at Cornell.

The Sunday evening non resident speakers at Barnes Hall for the past month have been Dr. Thomas K. Beecher, Mrs. Ballington Booth, Rev. Theo. Cuyler, and Prof. Burnham, of Colgate.

Mr. C. J. Field, of New York City, President and Chief Engineer of the Field Engineering Co., on Feb. 13 delivered a lecture at Sibley College on "The Construction of Electric Light and Railroad Plants."

The Cornell Alumni of Chicago and vicinity banqueted on January 29 at the Auditorium Hotel. President Adams, of Cornell, went west to attend. President Harper, of Chicago University, and Gen. Miles, of the Army, were among the seventy-five present.

During their western trip the Glee, Banjo, and Mandolin Clubs will give concerts as follows: Rochester, March 25; Buffalo, March 26; Erie, March 28; Cleveland, March 29; Detroit, March 30; Ann Arbor, March 31; Jackson, April 1; Grand Rapids, April 2; Chicago, April 4; Toledo, April 5.



TRIPLE EXPANSION EXPERIMENTAL ENGINE AT SIBLEY COLLEGE.

THE CRANK

THE SIBLEY

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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

THE NEW EXPERIMENTAL ENGINE FOR SIBLEY COLLEGE, CORNELL UNIVERSITY.

BY PROF. R. C. CARPENTER.

The experimental engine which has been in progress of construction for the past eighteen months is now installed in the Laboratory of Sibley College. This engine was especially designed for experimental purposes, and many of the features which are necessary for its intended uses would be unnecessary, and in many cases objectionable for an engine of the same type, intended for any single specific purpose. The need of engines designed for experimental purposes, which do permit a greater variation in the adjustment of working parts than is considered possible with the usual engine, has been felt for several years in nearly every technical institution of the country, and to fill this pressing need many of the institutions have already provided themselves with such engines. The investigations which can be carried out on such engines will, it is believed, have an important bearing on future methods of construction, by pointing out defects in present methods, and indicating the probable direction in which improvement is possible.

There is a wide field of investigation, and a great opportunity for improvement still open regarding the steam engine, and this improvement must come as the result of carefully conducted experiments. It is true that many, perhaps most, of the early improvements of the steam engine, were made in advance of scientific knowledge regarding the properties of steam, and in ignorance of the relation between the laws of heat and steam pressure, but the conditions now are changed and improvements which are yet to be made, and it is very certain that many will be made, must be worked out on a very different line.

A study of the early history of the steam engine shows that the first achievements were due as well to improvement in the mechanical arts of construction as in those of design, and that frequently the greatest difficulty that the early inventors experienced was in providing a suitable mechanical structure for the ideal mechanism existing in the brain. Thus the engine of Watt was only made successful by the business ability of Boulton and the mechanical skill of Murdock. The locomotive was a failure for years until the mechanical genius of Stephenson gradually worked out better methods of construction, and workmen were trained to produce mechanism that would withstand the stresses produced by high steam pressures.

The possibilities of the steam engine were not known until the science of thermodynamics was deduced by Rankine and Clausius. The revelations of this science, which is now fixed on a firm basis, indicated at once despite the great power developed, that the steam engine was a wasteful machine, that its efficiency was very low, and that there was a consequent opportunity for great improvement. The science did more than this, it pointed out the particular directions in which the engines were wasteful, and it indicated closely that barrier or limitation which once attained no farther improvement would be or could be possible. Since that time many improvements have been made in the steam engine, and its efficiency has been slowly and steadily increased. These improvements have come, not from the discovery of any new principle, but by the application with improved methods of those already known, and by the slow processes which result from experimental work. No one questions that many of the late improvements are due to the experiments and researches of Hirn, Halleure and Reynolds in Europe and of Isherwood, Emery and Thurston in our own country, yet most of these experiments, valuable as they may be, were made on engines in which the variable and adjustable features were exceedingly limited, and many questions of practical importance were on that account left for later investigators with special experimental engines. Numerous experiments have been made in recent years on the steam engines of the ordinary commercial type, and it would seem that all has been done that can profitably be done with such engines. What is needed now, it is hoped can be supplied by systematic investigations on the type of engine recently supplied to Sibley College.

The engines which are designed for experimental purposes by different experimentors are, as might be expected, far from uniform. While they differ very much in form, they do generally agree in possessing the following features which are not found on the ordinary commercial engines.

1. They are arranged so as to be capable, with slight changes, of representing several classes of engine, as simple, compound, or triple-expansion, and condensing or non-condensing for each class.
2. Great range of adjustment of admission valves and exhaust valves.
3. Means of reheating steam between or at any of the cylinders.
4. Dynamometers for measuring the work delivered.

THE SIBLEY EXPERIMENTAL ENGINE.

The Sibley experimental engine is designed so as to permit a greater variation in conditions than in most, perhaps any, of the experimental engines heretofore built. The engine consists of three separate Corliss engines, so arranged that they can be run singly or in combination as triple-expansion, or compound, and in either case as condensing or non-condensing.

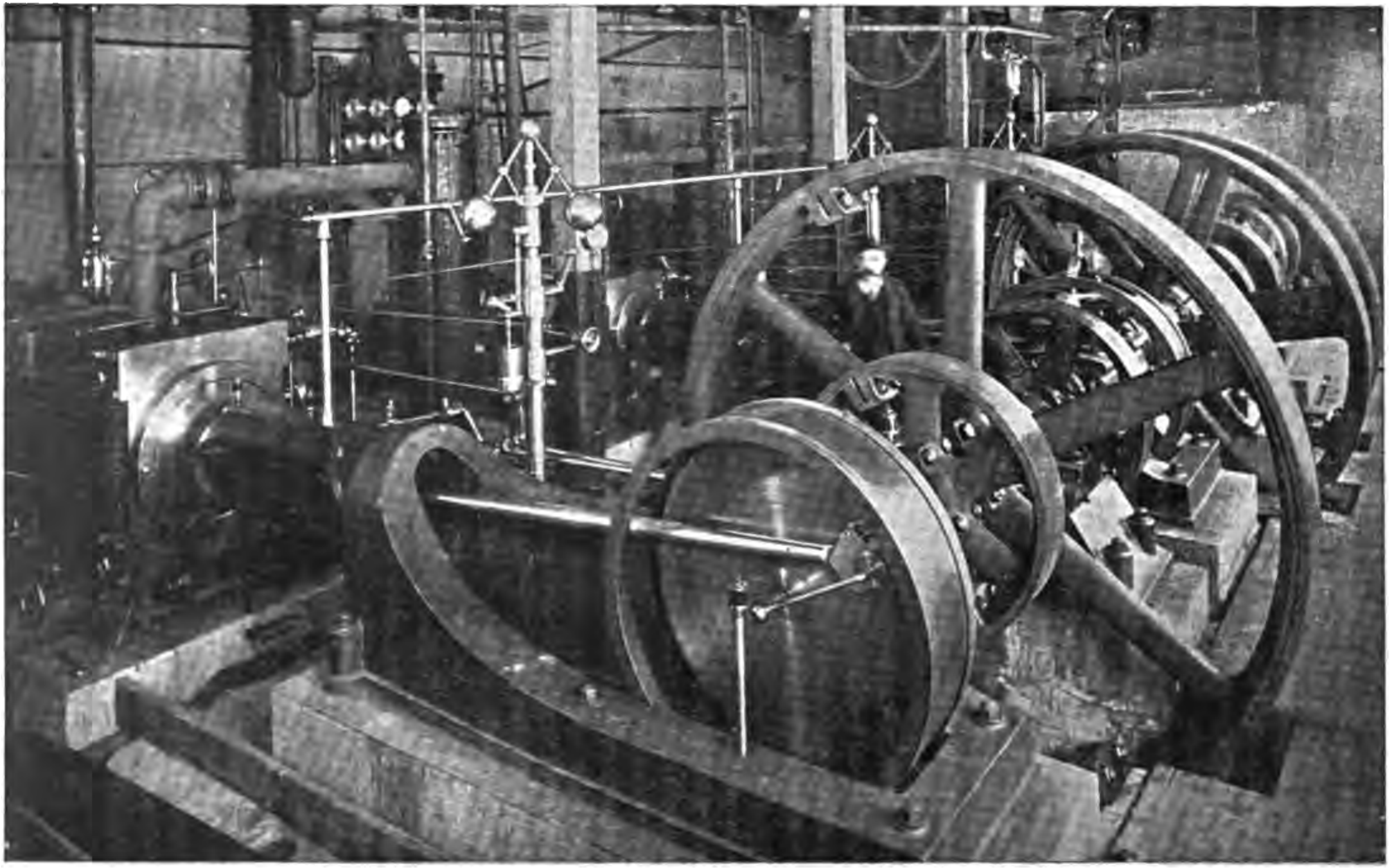
The small or high pressure engine is 9 inches diameter 36 inch stroke, the intermediate, 16 inches diameter 36 inches stroke, the low pressure 24 inches diameter 36 inches stroke. The high pressure cylinder is designed for steam of 150 pounds pressure, the intermediate for steam of 70 pounds pressure and the low for steam of 40 pounds pressure. The intermediate and low cylinders are provided with pop-safety valves set at the maximum pressures which should be carried, so that by no possible accident can a dangerous pressure be carried in these cylinders. The advantage of this peculiar valve, for an experimental engine, lies in the ease with which it can be adjusted for different degrees of expansion. To secure the same freedom of adjustment with regard to the exhaust, a separate eccentric is provided which is connected to an independent wrist-plate. By changing the angle of the eccentric the exhaust opening can be regulated independently of the admission. The general features of this engine are shown in the view (see page 219) from which it is noticed that each engine is provided with a fly wheel 10 feet in diameter, and a smaller brake-wheel four feet in diameter. By removing bolts in the flanges of the main pipe, we are enabled to produce three independent steam plants, each of which can exhaust into the air or into a Wheeler Condenser. In order to successfully operate in this way each engine is provided with an independent governor.

The general features of the valve gear are shown in the engraving (see frontispiece,) showing the general appearance of the engine from the west side. The external appearance is not especially different from that of any Corliss engine, except in the addition of the back-wrist-plate to operate the exhaust valves. In usual conditions of running one governor alone will be operative, which is the one on the high pressure engine, the other valve gears being operated with fixed cut-off; provision is made, by connecting the first governor to a long horizontal rod over the engines, for operating all the valve gears by the governor of the high pressure engine.

Each governor is provided with an adjustable hand cut-off, that can be operated at any time when the engine is running. In the usual operations of starting it is customary to let the cut-off occur at full stroke in the low pressure and in the intermediate cylinders for a few revolutions, then to adjust this cut off by hand until the pressures in the receivers are respectively seventy and forty pounds. When the governor is attatched to the rod leading to the other governors, the hand cut-off attatchment is not used, and the steam will be cut-off in each cylinder as required to maintain the speed.

Each engine is provided with steam jackets, and the intermediate receivers between the steam cylinders are also jacketted, so that the steam can be reheated in various positions on its way from the high pressure to the exhaust. The engine can also be operated without the jackets and thus the comparative economy of steam jackets can be tested.

The engine was designed by Mr. Edwin Reynolds, and constructed by the firm of E. P. Allis and Co. of Milwaukee, Wisconsin. The engine was erected by Mr. Wm. Bradshaw assisted by a former student of Cornell University, Mr. M. N. MacLaren Jr. Little need be said of this well known firm, since some of



the most famous engines of the world are monuments of their skill and ability. Of the recent work done by this firm may be mentioned the experimental engine of the Massachusetts Institute of Technology, which is of the same size as the Sibley experimental engine, but differs somewhat in form, and is not arranged with so many adjustable features. This engine has shown a steam consumption as low as 13.9 to 15.6 pounds per indicator horse power per hour. Also the engine recently installed for the Narragansett Electric Light Co. at Providence, R. I., which has shown the remarkable low consumption of 12.8 pounds of steam per indicated horse power per hour and is perhaps the most economical engine ever constructed. This latter figure would correspond to a coal consumption as low as 1¼ pounds per indicated horse power, and indicates better than any laudatory description the character of the work this firm is capable of doing.

The Sibley engine, while intended principally for experimental purposes, will also be arranged so as to be of service, in case extra power is needed, either for the purpose of electric lighting, or for power in the shops or laboratories. For experimental purposes each brake weeel will be fitted with a self adjusting brake, arranged so that it can readily be taken off and hoisted to a position where it will not interfere with the running of the engine for power purposes. The exhaust steam will be condensed in a Wheeler surface condenser, and measurements of the amount used will be made from the condensed steam. The steam used in the cylinder and receiver jackets can be separately drawn off, and the amount of heat absorbed can be definitely measured. Every opportunity will thus be provided for measuring indicated and developed horse power, and the steam used in all and every part of the system.

The number of experiments that can be performed on the engine will be limited only by the number of investigations desired. The different combinations that can be made of the engine are very numerous. The following are a few of the most important:

1. Three simple engines, each of which may be operated condensing or non-condensing, jacketed or non-jacketed, making a total of twelve combinations.

2. Two compound engines, each of which may be run condensing or non-condensing, with one or both cylinders jacketed or non-jacketed, with the receiver jacketed or non-jacketed, making a total of twenty-four combinations, or conditions in which the engine can be run.

3. It can be run as a triple expansion engine, condensing or non-condensing, with any or all or none of the cylinders or receivers jacketed. In this case we have a total of foty-eight different conditions in which the engine can be run.

4. Besides these principal combinations the engine can be run with high pressure steam in the larger cylinders and low pressure steam in the smaller cylinders, and in addition each combination of the engine can be operated with various positions of the valves for each condition as before.

The dimensions of the engine, which will be important considerations in any test that may be made, are as follows:

GENERAL DIMENSIONS OF ENGINE.

Diameter of High Pressure cylinder	9	inches
" " Intermediate Pressure cylinder	16	"
" " Low Pressure cylinder	24	"
Length of stroke	36	"
Revolutions per minute, 90.		
Diameter of fly wheels	10 feet	
Width of face of fly wheels	17	"
Number of fly wheels, 3.		
Diameter of brake wheels	4 feet	
Width of face of brake wheels	10	"
Number of brake wheels, 3.		
Diameter of High Pressure crank pin	3½	"
Diameter of Intermediate Pressure crank pin	7	"
Diameter of Low Pressure crank pin	3½	"
Length of crank pins	3½	"
Length of connecting rods	9 feet	
Diameter of main bearings	7	"
Length of main bearings	13	"
Length of pillow block bearings	10½	"
Distance between centre lines of High Pressure and Intermediate Pressure engines	14 feet	
Distance between centre lines of Intermediate Pressure and Low Pressure engines	12 feet 6	"
Rated horse power, 175.		
Floor space occupied 23 feet 9 inches × 31 feet 7 inches.		

HIGH PRESSURE CYLINDER.

Steam ports	⅝ in. × 12	inches
Exhaust ports	1⅛ " × 12	"
Diameter of steam ports	3½	"
Diameter of exhaust ports	3½	"
Thickness of steam space in jacket	½	"
Diameter of piston rod	2$\frac{5}{16}$	"
Diameter of steam inlet	3	"
Diameter of exhaust outlet	5	"

INTERMEDIATE PRESSURE CYLINDER.

Steam ports	1 in.	× 20	inches
Exhaust ports	$1\frac{1}{4}$ "	× 20	"
Diameter of steam port		5	"
Diameter of exhaust port		5	"
Thickness of steam space in jacket		$\frac{3}{16}$	"
Diameter of piston rod		$2\frac{5}{16}$	"
Diameter of steam inlet		5	"
Diameter of exhaust outlet		6	"

LOW PRESSURE CYLINDER.

Steam ports	$1\frac{3}{8}$ in.	× 28	inches
Exhaust ports	$2\frac{1}{2}$ "	× 28	"
Diameter of steam ports		$6\frac{1}{2}$	"
Diameter of exhaust ports		$6\frac{1}{2}$	"
Thickness of steam space in jacket		$\frac{1}{4}$	"
Diameter of piston rod		$2\frac{5}{16}$	"
Diameter of steam inlet		6	"
Diameter of exhaust outlet		8	"

All the moving parts were weighed before they were put in place. The weights are as follows:

Fly wheels	20,807	pounds
Brake wheels	5,264	"
Crank shaft and eccentrics complete	9,958	"
Total weight of crank shaft, fly wheels, brake wheels, and eccentrics	36,029	"
Weight of High Pressure piston and cross head	$378\frac{1}{2}$	"
Weight of Intermediate Pressure piston and cross head	503	"
Weight of Low Pressure piston and cross head	790	"
Weight of High Pressure connecting rod	281	"
Weight of Intermediate Pressure connecting rod	341	"
Weight of Low Pressure connecting rod	282	"

The connecting rods were suspended on knife edges and the time of their vibration was taken as follows,

	End on Knife Edge.	Time of 100 Vibrations.
Low Pressure	Crank end	4 min 45 sec.
	Cross head end	4 " $44\frac{4}{5}$ "
Intermediate Pressure	Crank end	4 min. $57\frac{3}{5}$ sec.
	Cross head end	4 " $41\frac{1}{5}$ "
High Pressure	Crank end	4 min. $44\frac{3}{5}$ sec.
	Cross head end	4 " 45 "

RECEIVER DIMENSIONS.

HIGH PRESSURE RECEIVER.		INTERMEDIATE PRESSURE RECEIVER.	
Length	11 ft. 7 in.	Length	11 ft. 7 in.
Diameter	14 "	Diameter	20 "
Number of tubes	15	Number of tubes	19
Diameter or tubes	$1\frac{1}{2}$ "	Diameter of tubes	$2\frac{1}{4}$ "
Receiver volume	8.2 cu. ft.	Receiver volume	15.8 cu. ft.
Heating surface	62.34 sq. ft.	Heating surface	119.8 sq. ft.

ELECTRIC RAILWAY CONSTRUCTION.*

BY C. J. FIELD, M.E.

The subject of electrical railway construction offers to the prospective electrical and mechanical engineer one of the most interesting fields for work in these professions, and one in which the future development promises very rapid strides and a golden future for those who are actively and successfully engaged in it. The success of electric railroads is assured, and their development today, in the operation of over seven thousand miles of road in this country, ninety-five per cent. of which have been built and constructed in the last two years and a half, is an indication of the success with which this system is meeting for street car traffic. Electricity has done more for good rapid transit in city and suburban traffic than any other form of motive power which has been introduced and used for this class of work. It is unnecessary for me to go here into a history of the progress which has been made. We see it on every hand.

The first part of our subject which we will consider is the question of power station work. The point of requirement in a successful power station, is that the station should be designed to conform to the machinery, and not the machinery be made to conform to the building. In other words, the station should be laid out by the electrical and mechanical engineer who knows more fully the requirements and needs of such a building. Therefore, this shows in the very beginning that in electric railway construction the engineer has to be not only an electrical engineer, but a mechanical engineer and an architect. For small and less expensive styles of construction, the best practice that I can indicate in this respect is to follow closely the lines of New England mill construction, as adopted for this kind of work. It gives you as close an approach to fire proof construction as is obtainable with the large use of wooden materials, and is what is called slow burning construction. For power stations of larger size, where the needs and requirements are greater, the building should be fire proof in every sense of the word, and should be entirely a brick or stone building, with iron trussed roof and fire proof covering.

I have illustrated several types of power stations as showing this kind of construction, and as I have carried it out on some of

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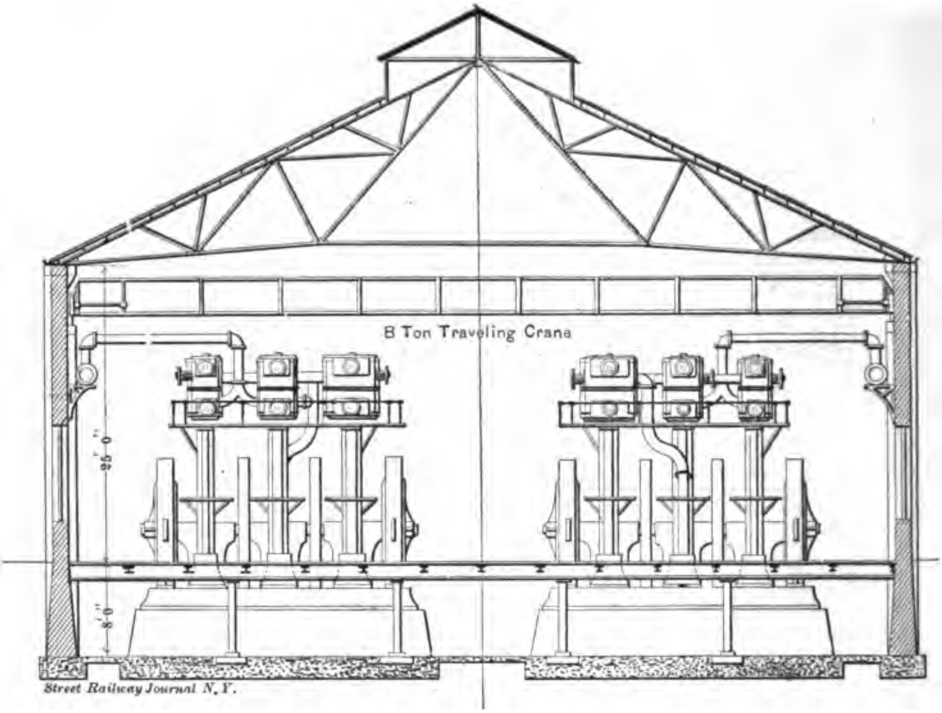
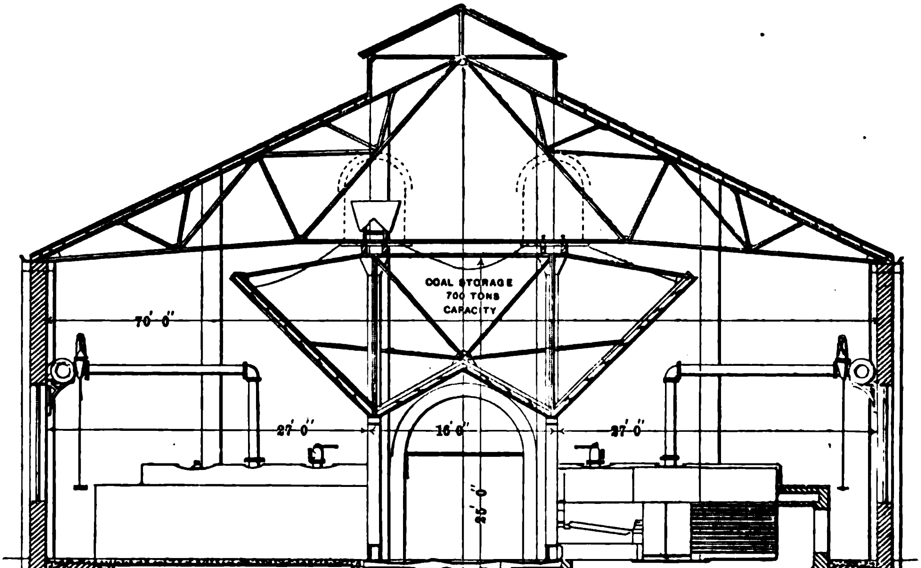
* Abstract of a lecture delivered at Sibley College, Cornell University, Feb. 12, 1892.

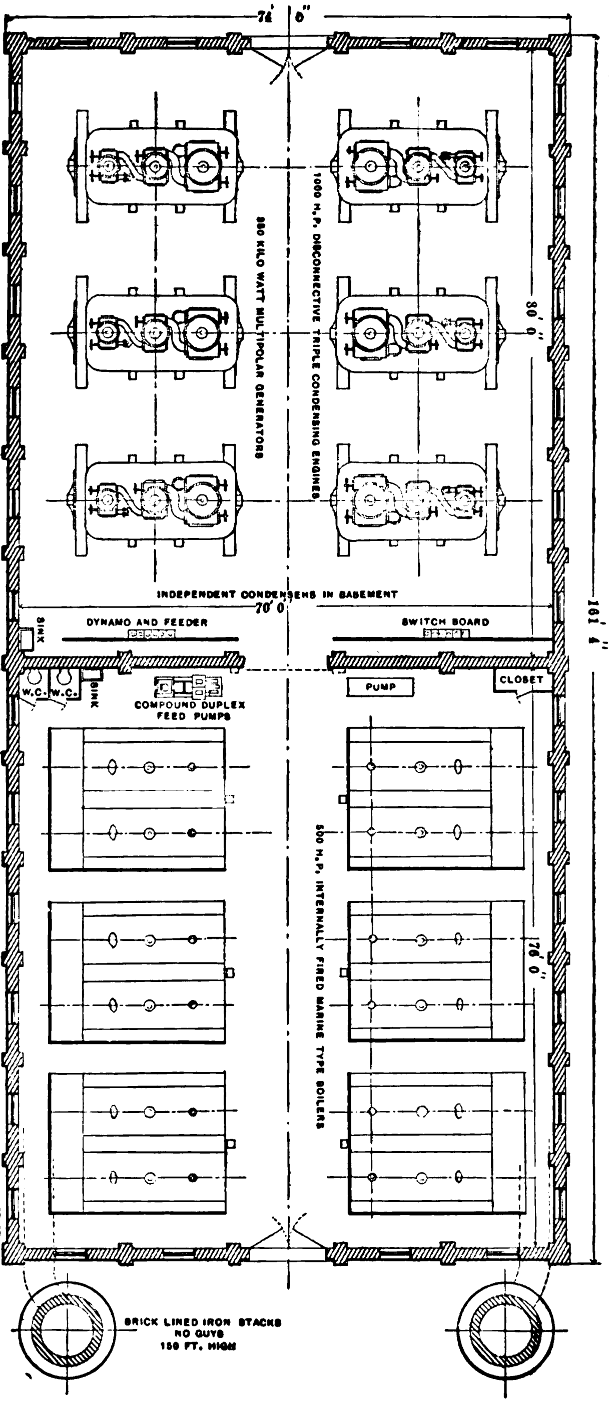

8 Ton Traveling Crane
25' 0"
8' 0"
Street Railway Journal N.Y.


COAL STORAGE
700 TONS
CAPACITY
70' 0"
27' 0"
16' 0"
27' 0"
25' 0"
FLUE
TO
STACK
INJECTION
WATER
DISCHARGE
WATER
Street Railway Journal N.Y.
FLUE
TO
STACK

our work. The building should be trussed roof, leaving clear space unincumbered by columns or other obstructions, and the engine and dynamo room should have traveling cranes of sufficient capacity to handle any of the engines or generators. The boiler room should be so located in reference to the engine room as to obtain best arrangement of piping, etc. The station as a whole should be laid out to give the most economical operation and the best surety for reliability in furnishing of power.

The steam and electric plant are closely allied to one another as regards the capacity and size of engines and generators. You may sum up these requirements of engines and generators as follows: That the number and size of the units should be such as to operate the station with the fewest number of units of engines and generators consistent with economy and reliability. As for instance, a 2,000 H. P. station divided into four units of 500 each, a 6,000 H. P. station, six units of 1,000 H. P. each; or in some cases it is preferable to divide one of the units in two, to get a small unit for special light work at night and any other time when it is required. The engine and generator should be as closely connected together as possible. Avoid, by all means, counter shafting. It is an unnecessary expense, and the most unreliable factor that can be added or introduced into such a power station. Belt to the generators, one or two, as the case may require; or they may be attached to each engine. To a 500 horse engine, 400 kilowatt generator capacity is the proper amount. The question comes up here, of loading the engines up to their capacity. You have not a case of a factory being built for a prospective future development. A station wants to be laid out for this development, and room for added units as they may require, but the generators connected to each engine should be of such a size as to fully load the engine under general conditions. The engine will stand as much and more overload, if of a proper kind, as the generator. Therefore at its normal capacity for the generator, the engine should be cutting off at about one-third stroke.

The best practice to-day is belting of the generators directly to the engine, as stated. We are fast approaching though, and developing the question of coupling the generators direct to the engine and operating them at the same number of revolutions. This entails a different type of machine, and one which is being rapidly developed now for commercial use in this country. We have illustrated a station of this style as showing the most economical arrangement, building, etc. A station laid out with the genera-

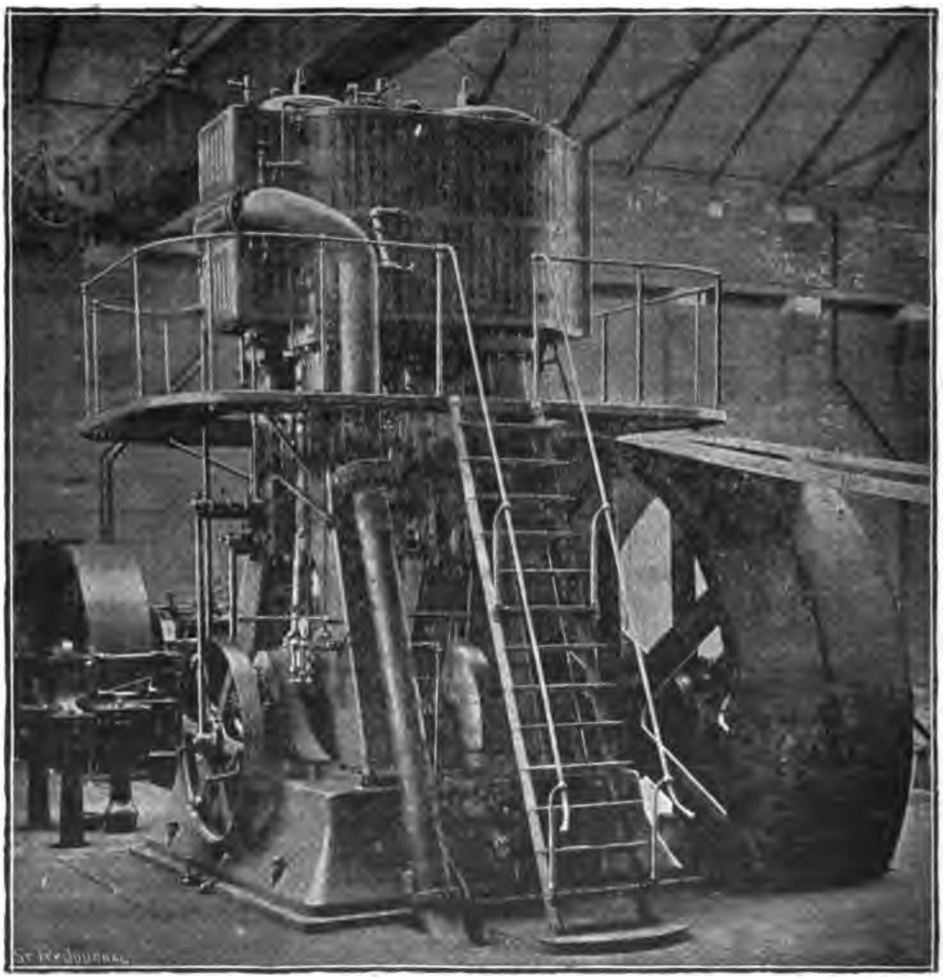

74' 0"
1000 H.P. DISCONNECTIVE TRIPLE CONDENSING ENGINES
550 KILO WATT MULTIPOLAR GENERATORS
30' 0"
INDEPENDENT CONDENSERS IN BASEMENT
70' 0"
161' 4"
SINK
DYNAMO AND FEEDER
SWITCH BOARD
W.C.
W.C.
SINK
COMPOUND DUPLEX FEED PUMPS
PUMP
CLOSET
500 H.P. INTERNALLY FIRED MARINE TYPE BOILERS
76' 0"
BRICK LINED IRON STACKS
NO GUYS
150 FT. HIGH

Street Railway Journal, N.Y.

tors belted to the engines, will require for station building complete four to five square feet of floor surface per H. P. One laid out for direct connection—that is, generators coupled direct to the engines, will require not to exceed half of this; thereby reducing cost of our building and real estate fifty per cent.

High speed engines as introduced on railway work several years ago, were poorly adapted to stand severe strains and shocks incidental to the variations and load on this kind of work ; and therefore, in the eyes of many engineers, were generally condemned for railway work, and a Corliss engine obtained a preference. High speed engines now, up to 200 H. P. are built sufficiently heavy to stand the strains for this kind of work, and are giving good service and economy when so built. When we reach over 200 H. P. or 250 at the most, we have got to meet the fact of length of stroke, clearances, valves, etc., and the single valve high speed engine on questions of general economy, etc. is ruled out when this limit is exceeded in good practice. The engine, therefore, best adapted for this work is one which will combine the advantages of the high speed in regulation and the advantages of Corliss, in clearance of four valves, etc. Such an engine has been recently developed and introduced on the market, and is specially adapted for belting direct to the generators or coupling direct to shaft. It operates at about 10 to 20% higher rotative speed than the Corliss, and considerably lower than the high speed, and the economy on variable loads is equal to the Corliss. One of these types of engine is that built by the Lake Erie Engineering Works, which we have illustrated here, and which we have introduced in several of our power stations. The boilers best adapted for this kind of work are some type of boiler which will give economy in evaporation, economy in space and ample steam capacity to stand a pull on boiler due to the variable loads. The boiler must also be one which is adapted to carry high steam pressure; in compound 125 to 140, triple condensing 160, triple non-condensing 200 lbs. The boiler most widely known and used for these high pressures, and which has been fully developed in modern practice, is the marine type of return tubular, internally fired, boiler, commonly called Scotch boiler.

The next question of importance, and the most important in the electric part is motors, car bodies and trucks. Electric motors for railway traction have had a marvellous development in the past two years, and at present they seem to have got down to what may be called good standard practice. Motors on railway work started off with double reduction type, that is, double gear wheels and speed gear about 11 to 1. At present the standard motor is single reduction with only two gears, geared down about 5 to 1, and the gears boxed in oil, removing the trouble of noise, etc., and we also have on the market now, gearless motors, directly mounted on the car axle, and running at the same number of revolutions as the wheel. The size motors usually introduced now for standard work on say an 18 or 20 foot car body, is two 20 H. P. motors. The question of the size of car body is also a serious one. A 20 ft. car body for a single truck is about the



limit for good construction, and the operation with a small wheel base is 7 ft. In very few cities can a longer wheel base than this be used. Large cars with 25 and 28 ft. body, and with double trucks for heavy city traffic, are being largely introduced to do away with the question of running trail cars. In some places these large cars are meeting with favor, and in others not. It seems to be a question of consideration for the kind of traffic in each case. Trucks also are an important part of the car equipment. Secure a truck that will carry the car well and give a maximum traction for driving the car and prevent the oscillation due to the short wheel base. Truck development in this respect in the last year has been very marked in its improvement.

The track construction for electric railway work has required more overhauling than any other part of the system. The old street car track with its flat rail laid on stringers, is more behind the time than any other part ot their equipment. In the best practice at present we are building the track equal to steam railroad bed, using a girder rail from 60 to 80 and even 100 lbs. weight per yard, set on chairs ; or in case of the 100 lb. rail, 10 inches deep, spiked directly to the ties. The need for this depth of rail is on account of the block paving which is generally prevalent where electric roads run.

Line construction is one of the parts of the work in which good engineering tells in the operation and reliable running of the road, and in which the public are largely interested, owing to the added safety and reliability of the system of good work in the streets. In the larger cities we are using iron poles almost entirely, set about 6 ft. in good Portland concrete, and spaced about 125 ft. apart. Where streets are wide enough to permit of the spreading of tracks to 6 ft. centre pole construction may be used. Otherwise cross suspension, with the poles placed on the curb line, is necessary. One of the principal requirements for good construction is a well built line with double and triple insulation between the trolley wire and ground, and feed wire and ground, to prevent any short circuiting of lines ; also to have ample feeder wire capacity. A great many roads have been built, figuring the feeder wire capacity for the normal conditions. Feeder wire capacity should be based on the worst conditions which can exist on any line, and the heaviest kind of work. It is just then you want the power, and want it at its full potential or pressure. By putting feed wires in on this basis you will save the cost of them in one year on motor repairs by saving the motors from the strains they have been subjected to of doing their work with half the pressure they ought to have just when they most need the full pressure. Feed wire suould be so distributed, connected and arranged as to obtain best control of the system and distribution of it into separate circuits and parts. In larger cities, where a large number of feed wires are distributed from one central power station, we are commencing to place our feed wires under ground, thereby removing largely the question of unsightliness of overhead construction. This is a large added expense in the installation, but seems warranted in many cases. It requires, though, the best kind of construction on this underground work ; more so than any other, as we are dealing with a grounded circuit, and any leak or trouble on our underground feed wires means a short circuiting of them.

One of the first questions which a street railway manager asks, in talking of equipping electrically, is what it is going to cost. I have carefully prepared a table here, which is on the general basis on which a street car man figures, of cost per mile of double or single track. This table of cost will be found very useful in making general estimates. It is based on the class of construction work I have been describing. It is divided into such parts as will enable a careful review of it in all respects.

COST OF EQUIPMENT.

Per mile of double track for cities, assuming four minute service and 25 H. P. per car in capacity of power.

Power Station :—Brick building, iron trussed roof, traveling crane, stack, etc., per 100 H. P.,	$ 1,500
Steam Plant :—Engines, boilers, belts, pumps, condensers, foundation and setting, per 100 H. P.,	5,000
Electrical Plant :—Generators, switch board, foundations, setting, etc., per 75 E. H. P.,	3,000
Car Equipment :—Motors, car bodies, trucks, complete for four cars,	13,000
Track Construction :—Seventy-two pound girder rails, and all other materials, paving, labor, etc., for one mile of double track,	22,000
Line Construction :—Iron poles, line material, feed wires, curves, etc., and feeding to Central Power Station,	7,500
General Sundries—And miscellaneous, including engineering and superintendence,	3,000
Total cost per mile of double track,	$55,000

Which is equal to $27,500 per mile of road in single track length, based on road being all double track.

In concluding, I wish to say a few words on the cost of operation and receipts. What does the electric railroad accomplish over a horse road? We know in general what it accomplishes in the sense of speed and increased business, but the serious question with a street railway owner and investor is, what return it is going to give him on the dollar invested. A careful review of a number of the large roads we have equipped, seems to indidate about the following: An increasing in the net earnings per car mile, of from two to three hundred per cent., with the invested capital increased fifty to one hundred per cent. We know of no case of a good, well built, well managed road that has not largely increased its net earnings, even on the increased invested capital. This is the result accomplished and the development of this work in a short three years. What the future promises, we can only guess at. And in closing, I would repeat again that I believe there is no field which offers such inducements to the electrical engineer, for a broad education, development, progress, etc., as electric railway construction work, which not only means electrical engineering in its broadest sense, but the kind of engineering that develops and brings out the young engineer in the shortest space of time, and makes him rely on his own ingenuity, and not depend on others.

WIRE ROD ROLLING.*

BY ROBERT W. HUNT.

I have selected for my subject the consideration of wire rod rolling, more especially as practiced in this country. While thinking of wire rods it is quite natural for our thoughts to embrace the products made from them, or wire itself. Of course you appreciate that wire rods are an intermediate product, representing an important step between the crude material and its higher development. It may prove interesting to briefly summarize the history of wire and the development of its manufacture. A work entitled, "A Treatise upon Wire, Its Manufacture and Uses, &c.," by J. Bucknell Smith, C.E., of England, will be found valuable to any of you who desire to more fully study this subject. I am indebted to it for some of my dates, etc.

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*Lecture delivered before the students of Sibley College, Cornell University, February 26, 1892.

The manufacture of wire was of very ancient origin; in fact, ages ago. It has been traced back to the earliest Egyptian history. Specimens are in existence which can be proven to date to 1700 B. C. The Kensington Museum has a specimen which was made in Minera 800 years B. C. Ancient literature contains many references to wire. From the ruins of Herculaneum, metal heads have been exhumed on which the hair is represented by wire. There is no question but this ancient wire was made by hammering out the metal, which was always bronze or of the precious group. This held true of all made previous to the fourteenth century, during which the process of forming wire by drawing or elongating the metal by forcing it through a conical orifice made in some substance harder than the metal treated, was invented. It is not until this time that we have any evidence of iron having been used. At first this drawing was by hand power, and it continued so until the latter half of the century, when a German named Rudolf built some kind of a power mill in Nuremburg. About 1500 this industry was introduced in France by one Richard Archal. A half century later, Queen Elizabeth of England granted permission to some Saxons to establish power wire drawing in her domains. Their first mill was driven by water power and located at Holywell. But for some time before this, hand drawn wire had been made in England. Pre-American ideas seem to have belonged to the business, as in 1630 Charles I, by royal proclamation, prohibited further importation of wire, because the home supply was sufficient both in quantity and quality. This must have given some encouragement to the "infant industry," as we are told that thirty-three years later the first really mechanical wire mill was built in England; this at Sheen. Protected inventive genius had asserted itself. Germany had been the first to develop power drawing and did not remain idle. In fact that country, Belgium and England have practically been the only European nations in which the wire industry has flourished. For years after its introduction into this country we depended upon them for our main supply of both billets and rods.

Before entering upon the consideration of rod mills, I will further follow the reduction of the rods themselves into wire. The rod is received by the wire drawer in the form of a coil; the rod of varying section and the coil of a weight depending upon the purpose for which it is intended. One end of the rod is pointed and somewhat reduced by machinery. The coil is then given a bath in mild acid to remove all oxidation, then washed in lime water to give a drawing surface and then dried in a proper oven. When ready for drawing the pointed rod is inserted in one of the holes of a drawing plate. This plate is generally of steel, but some factories use cast iron. The drawing holes are conical and the rod is inserted from the larger end. On the other side of the plate the pointed end is seized by power pincers and pulled until enough has been drawn through to allow of its being passed around and fastened to a drum or reel which is driven by power. Of course the rod is reduced in area and much elongated; this without any perceptible loss of metal. While passing through the plate it is kept lubricated with what is called wire drawers' soap or grease. After being drawn through this first hole it is put through a series of smaller ones until it has been brought down to the requisite size. But the compression and disturbance of the structure of the rod consequent upon these reductions has hardened it so much that at certain stages it is necessary to stop the process and soften the metal by annealing. After this it is again washed in acid, etc., and the drawing resumed. Iron and the harder grades of steel require five or six annealings while being reduced to the finer gauges of wire. But the manufacture of soft steel and the details of rolling it into rods have been so perfected, that soft steel rods can now be drawn into fence wire without any cleaning or annealing. After the final drawing the wire is finished in various ways, depending upon the purposes for which it is intended. We will not take time to consider them.

No matter of what metal the wire may be composed, the same general system of drawing is used, of course varying more or less with the metal. Including gold, silver, platinum, copper, etc., the commercial sizes of wire run from $\frac{1}{4}''$ to $\frac{1}{7000}''$ in diameter. The human hair is given as averaging $\frac{1}{500}''$ in diameter; the silk threads of the worm $\frac{1}{5000}''$, while the hair lines in optical instruments are of platinum wire as fine as $\frac{1}{7000}''$. In fact, that metal has been drawn to $\frac{1}{25000}''$. These figures are interesting and instructive, but the mills which we will consider are for the production of rods intended for the cruder forms of wire. We will now turn to their consideration.

In the early days of iron wire the metal used was made from the ore by direct processes, and with the aid of charcoal as fuel. As only the richer, and as it happened, purer ores, were utilized, the resulting wrought iron was of superior quality, possessing extreme softness. While the art of wire making was advancing, many other changes occurred in iron metallurgy, particularly as related to the extraction of the metal from the ore. These, as well as those changes in the subsequent working of the iron, did not all tend toward maintaining so high a class of material. As has always been the case, cheaper production was demanded, in both the crude iron and finished product. To meet this condition by successfully handling the cheaper but poorer iron, more complete and in every way mechanically better rod mills were required. For the higher grades of iron wire, pure metal has always been and is still a necessity. The iron made in the direct charcoal bloomery was hammered into cylindrical masses called "blooms." These were heated in furnaces, and in the earlier days further hammered to smaller sections called "billets," which were again heated and hammered into rods. Later the blooms were reduced to billets and they to rods, between the grooved iron cylinders or rolls of rolling mills. I believe the Germans were the first to roll wire rods, and in their earliest mills the rolls were without grooves, being perfectly plain cylinders between two of which the billet was drawn by compression and by their motion forced through perforated plates placed in front of them. Evidently this idea was taken from the wire drawing plates. This could not have worked very satisfactorily, and it was not long before the grooved rolls were invented. After the invention of the blast furnace came puddling by which the pig or cast iron was converted into wrought iron. But the resulting bars were too unsound and of too low ductility to permit their being rolled into wire rods; hence they were cut into pieces which were piled one on the other, some four to six high, heated in a reverberatory furnace and rolled into billets. These billets were again heated and rolled into rods. You no doubt fully understand that such reworking of wrought iron increases its ductility and also its tensility. As the business progressed many improvements were made, and in no direction more than in the rod mills. The use of cheaper materials, larger productions, with less labor, were the great aims. Advancement was accomplished, but so long as iron was the metal to be treated the highest possibilities of development could not be reached. It was not until the introduction of soft steel that these were made possible.

The Belgian engineers made a great advance by the invention and adoption of a mill arrangement which has ever since been known as the Belgian Mill. In this the rod mill is divided into two sections, the one standing behind the other and about thirty feet away. The first section has one set of rolls, which are usually of 12″ pitch line and are known as the roughing rolls. These are driven direct from the engine shaft. The other section is composed of several sets which are called the finishing rolls and are of 9″ pitch and are driven by a belt from the engine shaft at several times the speed of the first section. On the original Belgian mills, all the manipulation was performed by hand. Later, various mechanical appliances have been successfully introduced which have reduced the number of men required to operate the train. A billet of 2″ to 2½″ square and from four to six feet long was about the preferred size. Owing to the comparatively slow speed of the roughing rolls, the skilled train-men had no difficulty in catching the billet with their tongs and passing this from one groove to another. By a few passes between the rolls it was much reduced in section and greatly elongated, so that when it came from the last pass it reached to the finishing section of the train. Here another workman seized it with tongs and entered it in one of the grooves of the faster running rolls, and as it issued from the rolls on either side of the train, workmen caught it with tongs, turned it half over so that the other faces of the piece should be brought against the upper and lower rolls, and then entered it in another groove of smaller size, and so on through grooves of decreasing size and varying sections until the rod was finished, when a tube or trough led it off to a reeling maching, on which it was formed into a bundle or coil.

Previous to 1869 all wire rods were rolled in this country upon ordinary guide mills, the manipulation of the material being entirely by hand. By "ordinary guide mills" I mean trains of rolls of about 9″ pitch, and having the several stands of rolls in the same line On these billets of about 1⅛″ square and 18 pounds in weight were used, and six tons of No. 4 gauge rods was regarded as a good day's or turn's work. Early in 1869 the Washburn & Moen Manufacturing Co., of Worcester, Mass., put up a continuous wire rod mill after the designs and patents of George Bedson, of Manchester, England. His first English patents were obtained in 1862. Mr. Bedson may be said to have been born in the wire business and devoted his life to it. He was connected with many of the leading wire manufacturing companies of England for many years; in fact, until his death. He was the originator of many improvements in both rolling wire rods and manufacturing wire. The Bedson type of continuous rod mills has a pair of rolls for each groove, and the many pairs necessary to complete the reduction of the billets to rods are arranged in a straight line, one immediately in front of the other. But to avoid the necessity of turning the rod during the rolling process, each alternate pair of rolls is placed with their axes in a vertical plane. Thus the first set will press upon the top and bottom of the bar, while the next set will bear against its sides, and so on. Of course as the bar is reduced in size it elongates, and to meet this, each succeeding pair of rolls is geared to run enough faster than the preceding pair to take up the "slack" caused by the elongation. You can appreciate that nice adjustment of speed is essential to the successful running of such a mill. Billets of 1⅛" square are used on such continuous mills, and in the early days referred to, they weighed about 80 pounds. Washburn & Moen expected to roll iron rods on their Bedson mill, but encountered so many difficulties that they were almost ready to give it up as a failure. Please remember that at this time the production of soft steel had not made much progress, and iron would not stand the strains put upon it while being rolled in the Bedson mill. Snarls, messes, and break downs were constant. These troubles were so great and their immense business so pressing that they built a mill of the Belgian type.

Fortunately it was not long before the developments of the Bessemer process gave soft steel to the trade. The use of this tough metal was the salvation of the continuous rod mill. During the struggle for existence of the Worcester mill, many changes and improvements were made in it. The well known American mechanical engineer, Mr. C. H. Morgan, was the general superintendent of the works, and he had for assistant in this mill a bright young engineer who has since made a name for himself and is now the general superintendent and chief engineer of the Washburn & Moen Co.,—Mr. F. H. Daniels. Up to this time the reeling machines upon which the rods were coiled after being finished, had always in all mills been turned by hand. After the rolling of the steel billets became a success, it was soon apparent that the necessarily slow movements of the reel would keep down the output of the rolls; hence a power reel was designed and put in by the Worcester management. Seven tons of No. 6 rods had been considered a fair turn's work. After the power reel went in the product was soon increased to over twenty tons per turn. The length of bed of the heating furnace was increased so that longer billets could be used, the length of which was finally brought up to 21′. The results were so satisfactory that the company put in another continuous mill, which was designed by Messrs. Morgan and Daniels. Naturally they made many improvements over the first mill. Rods are now finished on it at a speed of 50′ per second, and reeled with ease and certainty. Several of the improvements were patented by Messrs. Morgan and Daniels; I believe some jointly and others individually.

Since Mr. Morgan severed his connection with Washburn & Moen, he has designed and built a rod mill for the American Wire Co., of Cleveland, Ohio. This is also a continuous mill, and was started in 1888. Some very good production has been made upon it. In fact, it is claimed that in one ten hours, over 118 gross tons of No. 5 rods were rolled. But I believe the best record of weekly product has been 500 tons of No 8 rods for three consecutive weeks. On the same mill a production of 35 tons per turn for two weeks, of No. 9 rods, 0.148″ diameter, rolled from billets weighing 210 pounds, has been reached. This was a reduction of area of 99.89 per cent. The finished rods were 3,620 feet long. Previous to the building of this mill, a great innovation in rod rolling had been made by William Garrett, which we will discuss later. An important and radical feature of his system is the use of a billet 4″ square. This is of so great value that all of the later mills have endeavored to use that sized billet. In the Cleveland mill Mr. Morgan departed from the original form of Bedson mill by placing the axis of all the rolls in a horizontal plane, and turning the piece being rolled as it passes from one set of rolls to the next by means of properly formed boxes or guides. This enabled him to have a much stronger and less complicated mill.

Washburn & Moen have established a western branch of their immense establishment at Waukegan, Wis. They are there putting in a rod train from Mr. Daniels' plans, which will be somewhat different from any of its predecessors. It is not yet completed, hence I will not attempt its description. A few years after starting the first continuous mill at Worcester, the Roeblings, of Trenton, N. J., put down a mill on the Belgian principle. This has since been much improved and is now one of the best American mills, although I believe the output has never been brought as high as several of the others. The Trenton Iron Co., of the same city, have a Belgian mill. In 1876 the Cambria Iron Co., of Johnstown, Pa., built a rod mill after the designs and covered by the patents of Henry B. Connor. While all the rolls of the train were in a continuous line, at right angles to the mill engine, they were divided into groups, each succeeding one of which was driven at an increased speed by a line of shafting placed directly under the train. This mill was not as successful as expected, and after much experimenting it was altered and improved.

Mr. William Garrett was the superintendent of the rod mill department of the Cleveland Rolling Mill Co., Cleveland, Ohio, in 1882. In that year he built a rod mill for his company which was destined to mark an era in the American wire rod industry. Up to this time, as already stated, the continuous mills were using 1⅛" billets, the Belgian mills 2" or 2½" ones. To produce billets of these sizes upon any of the then existing billet mills, and under the prevailing practice, it was necessary to roll the steel ingot into blooms, re-heat the blooms, and roll to billets. Mr. Garrett desired to save the expense of the intermediate heating and rolling between the blooms and billets; hence he sought to invent a mill which would take a billet large enough to permit its being rolled direct from the ingot without any re-heating. He settled upon 4" square as being that size. Of course such a saving in heating and rolling was of great importance. To accomplish this, he went beyond the Belgian mill plan by putting in three separate trains of rolls, placed in echelon and driven at progressively increasing speeds. The first train ran at a slow enough speed to allow the workmen to handle the large and heavy billet, the second train much faster, and as the piece had by the time it reached these rolls become much reduced in section and elongated, the workmen could successfully contend with a higher speed and by the time the piece had reached the last train, which was running very fast, it was so pliable that the men could catch it with their tongs and enter it in the proper grooves. By this arrangement not only the use of larger billets was permitted, but it was made possible to have more than one piece in the rolls at the same time. This practice has grown until four are now constantly, and frequently five pieces, rolled at the same time. The success of this Cleveland mill was so great that since then Garrett mills have been put in at Beaver Falls, Pa.; Oliver & Roberts, Pittsburgh, Pa.; Braddock Wire Co., Braddock, Pa.; the Joliet Works of the Illinois Steel Co.; American Wire Nail Co.; the American Wire Co., Cleveland, Ohio; the H. P. Nail Co., and the Newcastle Wire Co., Newcastle, Pa.

In all the later forms of mill, excepting the continuous, use has been made of what is technically called the "repeater." I presume the first applied idea of this device was made by J. Bleckly, of England, in 1872; at least it is so claimed. He applied this device to a train of rolls which were four high. That is, there were two sets of two rolls each, placed one above the other in the same frame or housings. The sets were driven in opposite directions By means of a bent pipe placed with its orifices opposite grooves in both the upper and lower sets, he sought to catch the piece in the pipe as it came from the upper rolls, and carry it down to and enter it in the grooves of the lower set. In the later American mills other than the continuous, the rolls, other than the first and larger set, are but two high and those of each section stand in line, each set having but one pass; hence the American "repeater" guides the piece sideways from one set to the next, and thus from one pass to another. There is quite a controversy as to whom the credit should be given of the invention of the first practical repeater. I have reason to think that John Davis, of Cleveland, has a right to the honor. A later and better one was invented by Mr. McCalliff, of Columbus, Ohio. A still later, and by many considered best one, by Frank G. Tallman. But there are several others for which their friends claim superiority. By turning and carrying the piece from one pass to another, these devices save a large amount of labor. While the advocates of the continuous system admit that larger product can be obtained on a Garrett mill, they claim a saving in labor and loss by oxidation. When wear and tear are considered, which items embrace the labor and cost of repairs, I am inclined to doubt the justice of the claim. The accurate data of each item at the various mills is verv difficult to obtain. The Joliet Garrett Rod Mill, until very lately, held the best record of production. Champion honors now rest with the Beaver Falls mill, also built by Mr. Garrett. Of No. 5 rods they rolled in a single turn $143\frac{1680}{2240}$ tons, and in a week made 1,390 gross tons. How long they will be permitted to enjoy their honors it is difficult to foretell.

The Garrett train at the Joliet Works of the Illinois Steel Co. is divided into four sections. The first, or roughing rolls, is of 16″ pitch, and the intermediate train 12″, leading or first finishing 10″, and the finishing rolls 9″ diameter. The 16″, 12″ and 10″ trains are driven by one engine, built by the Allis Works of Milwaukee, and is of the Reynolds-Corliss type. It is compounded with 32″

× 60″ high pressure, and 64″ × 60″ low pressure cylinders. It runs at 84 revolutions per minute. The 9″ finishing rolls are driven by a 32″ × 48″ high pressure, Porter–Allen Engine, making 115 revolutions.

The 16″ train runs at 84 revolutions per minute.
" 12″ " " " 140 " " "
" 10″ " " " 310 " " "
" 9″ " " " 500 " " "

The finished rods are coiled on 5 power reels of the Garrett patent, which are operated by two men. Other than these reel men, there are eight men and four boys required to operate the train; these in addition to the chief roller, who has charge of the entire train. The labor of these is divided as follows: 3 men on the 16″; 1 man on the 12″; 2 men and 2 boys on the 10″, and 2 men and 2 boys on the 9″ train. Of course there is other labor to "take off" and carry away the coiled wire rods. These coils weigh from 130 to 150 pounds, with length of rods from 1,000 to 1,300 feet, depending upon the gauge of rod and other details of the various orders. As you already know, these are rolled from 4″ square billets, which are generally 3 feet long.

The American Wire Co. has one Morgan and one Garrett mill. The general arrangement of this Garrett mill is like that at Joliet, but there are several important variations. The trains are of 16″, 12″, 9″ and 9″ pitch. The first is driven by a 24″ x 42″ engine. The 12″ and 9″ leading trains are driven by a 26″ x 42″ engine, and the 9″ finishing train by a 24″ x 42″ engine. All high pressure and of the Porter–Allen type. The billets are carried by "telegraph" from the furnaces to the 16″ rolls, in the first set of which six passes are made. One pass is then given in the next pair of rolls, and the piece is carried by a trough or pipe to the intermediate 12″ train. In this three passes are made between as many pairs of rolls. The piece is carried from the first to the second rolls by a repeater and trough. A pipe conducts the piece to the 9″ leading train. This and the finishing train are in line, and eight passes are made in them, the piece being "repeated" from one set of rolls to another on the front side of the trains. It has been reduced from 4″ billet to rod in 18 passes.

Naturally, Mr. Garrett has improved on his previous efforts in each mill designed by him. All of his later mills have sloping floors leading into pits in front of the rolls, thus helping to keep the elongating, quivering and rapidly running out hot metal away from the rolls. Several other ingenious devices are used for the same purposes. In the old mill this work was all done by boys with hooks. The present mode not only saves labor, but is safer and allows increased product.

I have endeavored to briefly outline to you the history of wire making and wire rod rolling, and also to call your attention to some of the leading types of American mills. While I have mentioned the product which has been attained on several of them, it may not be amiss to give you a few figures which will enable you to comprehend the importance of this branch of the iron and steel business of our country. These figures will also demonstrate to you the remarkable way in which steel is replacing iron in other products than rails, and will also, I am proud to say, prove how independent we have become of foreign manufacturers. The official figures for 1891 have not yet been published, hence we must take those for 1890 as representing our last condition. At the same time, it is well known that 1891 will show even stronger in America's favor. In 1890 there were rolled in the United States 492,153 net tons of steel, and 19,798 net tons of iron wire rods, making a total of 511,950 net tons for the year. This is a total production of 2,820,377 net tons of rolled iron, and 3,925,243 net tons of rolled steel, of which 2,093,993 net tons were rails. Of the rolled iron but 15,548 net tons were rails. So in a production of 1,829,250 tons of rolled steel in other forms than rails, 492,153 tons went into wire rods, while in a production of 2,804,829 tons of rolled iron other than rails, but 19,798 tons were made into wire rods.

Less than twenty years ago, the production of steel rods in all countries was limited to the higher grades, and amounted to comparatively a small percentage of the total output. The growth of the industry in this country is shown by the facts that in 1888 the production of rods from both metals was 313,341 net tons, in 1888, 407,513 net tons, while in 1890 it was, as already stated, 511,951 net tons. I cannot give you the figures for the years anterior to 1888, as previous to that year they were not definitely ascertained. But as demonstrating how, as our own manufacture has advanced, we have gradually become independent of foreign supplies, we find that in 1886 our importation of iron and steel wire rods amounted to 153,401 net tons; in 1887, 167,292 tons; in 1888, 114,030 tons; in 1889, 73,758 tons, and in 1890 but 55,427 net tons. While we may not all agree as to the causes and the wisdom of some acts which have brought about this change, you must permit me to say that for one I am satisfied with it; and more than that, as an American, proud of it.

A very remarkable development in the use of wire has been in the increased production of wire nails in this country. The first American wire nails were made by William Hassall in 1851 or 1852, and the American Wire Co. of Covington, Ky., were the pioneers in the industry. And as with us all of such nails are now made of steel wire, the statistics give another evidence of the substitution of soft steel for wrought iron. While the large consumption of wire nails is a new thing in America, such does not apply to Europe; but it is also true that there, iron wire was until recently the material used in making such nails. Of course you know that the use of cut nails of wrought iron was the former custom with us. About 1883, nails cut from soft steel came into prominence. James M. Swank, in his annual report for 1890 to the American Iron & Steel Association says: "In 1884 the production of steel cut nails in the United States (including 500 kegs of combined iron and steel), was only 393,482 kegs, or 5% of the total cut nail production. Steel was afterwards rapidly substituted for iron, until in 1889 steel cut nails represented 69% of the total cut nail production of the country." He also says: "The maximum total production of cut nails was reached in 1886, with 8,160,973 kegs, and the maximum production of steel cut nails alone was reached in 1888 with 4,323,484 kegs." Now in 1886 the total production of wire nails was estimated to have been only 600,000 kegs. That you may appreciate the growth of the industry and the constantly increased substitution of wire for all kinds of cut nails, I have tabulated the figures.

KEGS OF	1886.	1888.	1889.	1890.
Cut nails of all kinds, ...	8,160,973	6,493,591	5,810,758	5,640,946
Wire nails, ...	600,000	1,500,000	2,435,000	3,135,911
Total, ...	8,760,973	7,993,591	8,245,758	8,776,857

In cut nails are included all railroad spikes, boat spikes and other heavy products which are classified as nails. Another tremendous item of American wire production is barb fencing. It is estimated that over 180,000 tons of this material were consumed by us last year.

Without enthusiasm in our chosen calling there is not much hope for complete success. My friend Mr. William Garrett has achieved brilliant success, and those who know him fully appreciate that he is the very embodiment of energy and enthusiasm. From him I have the following figures: "I have been figuring up somewhat on the extent of the barb fence industry of this country. Last year there were over 180,000 tons used. One rod of the Glidden barb fence weighs one pound. There are 320 rods in a mile. As the earth is 24,884 miles in circumference at the Equator and we have 1,122,222 miles of Glidden barb in 180,000 tons, there would be enough barb wire to lap around the world at that point forty five times. The distance from the earth to the moon is 273,000 miles. We could, from the barb wire made in this country last year, have four strands reaching from the earth to the moon, and have enough left over to go between the strands and make a "Jacob's Ladder;" the only drawback being that on account of the barbs, the angels would have to be careful of their wings."

All of the men who have brought the wire industry to its present status have the right to feel proud of their achievements. May to you, young gentlemen, come equal success in whatever walk of life you may enter.

CALIBRATION OF BROWN AND SHARPE MICROMETER CALIPER.

BY J. G. BROWN AND C. L. HOYT.

The calibration of a micrometer caliper, which is considered a standard instrument, is a matter of interest to all users of micrometer screws, since such a calibration will show to a considerable degree of accuracy, whether the micrometer is perfect, or in error and if the latter, the nature and extent of the error. Being interested to know to what extent the instruments used in the Mechanical Laboratory at Sibley College could be relied upon, at the suggestion of Professor R. C. Carpenter the following investigation was made.

The calibration was effected by comparison with a standard metallic grating upon the Rogers Ballou comparator. The caliper was rigidly clamped to the comparator, the axis of the screw being horizontal and parallel with the ways of the machine. The plug which forms the lower post of the caliper was removed. An iron block having a one-fourth inch rod screwed into one side was clamped to the small movable carriage in such a way that the rod played freely through the hole in the caliper and abutted against the end of the micrometer screw. The metallic grating was mounted upon this carriage. When the micrometer screw was advanced it pushed the carriage carrying the grating before it and the absolute amount of such displacement was read by means of a fixed microscope focussed upon the grating. A similar microscope served to show whether the caliper remained absolutely stationary throughout the investigation. Precautions were taken to secure perfect alignment of the parts by adjusting the cross-hairs of the microscope upon the axial graduation line of the caliper, and requiring it to traverse the whole length without deviation or going out of focus. This insured alignment in both horizontal and vertical planes. The grating used consists of a bar of metal highly polished on one side and ruled two thousand five hundred lines to the inch. The reading microscope is provided with two cross-hairs, one fixed and the other adjustable by means of a micrometer screw, the head of which screw is divided into one hundred parts, each representing a displacement of .00001 of an inch. Increments of even number of thousandths were taken, so that at each reading the fixed cross-hair should coincide with one of the lines of the grating. Any variation from this was measured by bringing the movable cross-hair into coincidence with the line of the grating corresponding to the reading of the caliper and reading its displacement from the fixed cross-hair, thus determining the error of the screw. The investigation showed that the micrometer screw could be adjusted to within one fifty-thousandth of the desired point. There was also a possible error of about the same amount in reading the grating, thus making a total possible error of one twenty-five thousandth. Readings were taken throughout the length of the screw with constant increments of .024 of an inch. Inasmuch as the head is divided into twenty five parts, this brought the reading upon each division successively, thus testing the accuracy of the graduation.

The readings showed little error, beyond that due to observation, throughout the first three-fourths of its length (one inch); during the last quarter of its travel, however, an accumulative error appeared, amounting at the end to .00012 of an inch, the actual length of the screw being .99988 of an inch. A number of readings were taken both of intermediate points and total length. A second micrometer of the same manufacture and pattern was also calibrated in substantially the same manner showing an error which gradually rose to .00025, midway in its travel, dropping at .7 to .00017 and again rising to a maximum at the end, of .00036, the error being as in the first case. The screw was therefore too short, its total length being .99964 of an inch. The instruments tested were of modern design, and have been in use about one year.

FLOW OF STEAM THROUGH AN ORIFICE.

BY J. KUHN AND R. T. MICKLE.

The amount of steam, its velocity and corresponding fall of pressure, are important quantities in many engineering calculations.

The theoretical calculations for the flow of steam through an orifice indicate that the pressure should fall in every case to that which will give the maximum outflow. Theoretical calculation would indicate that this pressure is independent of the back pressure, and is in every case about 58 to 60 per cent of the absolute pressure, producing the flow. From the known pressure the velocity can be computed, and if the fall of pressure is a certain per cent. of the absolute initial pressure the velocity of flow will be nearly constant and about 1400 feet per second.

The velocity cannot from the nature of the case be directly measured, and hence it becomes of great importance to know if the theoretical fall of pressure is correct. To determine this and also to test the correctness of Napier's rule for the flow of steam through an orifice, the following experiment was performed.

The apparatus for making the test was set up in the little engine room, and the steam was condensed in the Wheeler condenser. The apparatus was set up as follows: A globe valve was placed between the boiler and the apparatus to vary the initial pressures, next the valve was a tee to which a throttling calorimeter was connected for obtaining the quality of the steam entering. Next to this was placed the orifice which consisted of a pipe .502 inch diameter with the ends flared similar to a Venturi tube. At the middle of the length of the orifice a hole was drilled radially for a pressure gauge. Next to the orifice was placed a thermometer and gauge for obtaining the temperature and pressure of the medium into which the steam passed. The steam was condensed and weighed; time was taken with a stop-watch; starts and stop made running. All data was averaged and corrections made for the gauge calibrations. The readings taken were—1, the initial steam pressure; 2, thermometer; 3, manometer on calorimeter; 4, pressure in orifice; 5, pressure of the medium into which the steam passed; 6, temperature of the same, and weight of water. Runs were made under two sets of conditions; those marked A where the back pressure was near that of the atmosphere, the pressure being read from a manometer, and the initial pressures were varied, and those marked B in which the initial pressure was kept constant and the back pressure varied.

ABSTRACT OF RESULTS OF TEST.

Test A. 1st Trial.

Steam Pressure by Gauge. Lbs.	Gauge Pressure at Orifice. Lbs.	Back Pressure. Inches Hg.
101	55	9.0
99	53	8.0
99	49	8.0
96	47	7.5
94	45	6.8
94	52	7.7
100	55	6.0
98	50.8	7.5 Average.
92.9	48.5	7.5 Corrected.

Time of test, 18 m., 2⅘ sec.

Barometer 29.35.

Weight of flow, 330 lbs.

Quality of steam, 97 per cent.

Ratio of absolute orifice pressure to absolute steam pressure, .588 per cent.

Test A. 2d Trial.

Steam Pressure by Gauge. Lbs.	Gauge Pressure at Orifice. Lbs.	Back Pressure. Inches Hg.
80	40.5	0.4
76	38.0	0.8
71	35.0	—2.1
79.5	40.0	1.0
82	41.5	2.0
82	41.0	1.9
75	37.0	1.1
85	44.0	3.3
78.8	39.6	+1.5 Average.
78.9	36.6	1.5 Corrected.

Time of test, 22 m., 29⅖ sec.

Weight, 325 lbs.

Quality, 98.13 to 98.75.

Ratio of absolute pressure on orifice to initial pressure, 0.60.

Test A. 3d Trail.

Gauge Pressure. Lbs.	Gauge Pressure at Orifice. Lbs.	Back Pressure. Inches Hg.
41	16.25	—11.25
42	17	—10.75
38	15	—12.25
38	14.5	— 9.75
46	20	—11.25
40	16	—12.37
37.5	14	—11.37
40	16	—
39.5	15	—11.75
40.2	16.41	—11.5 Average.
36.2	13.41	—11.5 Corrected.

Time of test, 25 min., 49⅖ sec.

Weight, pounds, 205.

Quality $\left\{\begin{array}{l}99.7\\100.2\end{array}\right.$

Ratio of absolute orifice pressure to initial pressure, 55.

Test A. 4th Trial.

Gauge Pressure. Lbs.	Gauge Pressure at Orifice. Lbs.	Back Pressure. Inches
20	3	—18.5
20	3	—18.5
19	3	—18.5
20	3	—18.0
22	4	—17.75
22	4	—17.25
18	2	—16.87
20	3	—18.25
20	3	—18.25
20.1	3.1	—18.0
16.1	0.1	—18.0

Time, 24 min., 23 sec.

Weight, 120 lbs.

Quality $\left\{\begin{array}{l}100.2\\101.1\end{array}\right.$

Ratio orifice pressure (absolute) to initial pressure, .48.

TEST A. 3D TRIAL.

Steam Pressure by Gauge. Lbs.	Gauge on Orifice. Lbs.	Back Pressure. Inches of Hg.
57	27	—5.2
62	29	—4.9
62	28	—4.7
62	29	—4.5
62	29	—4.5
64	30	—4.5
61.5	28.6	—3.7 Average.
56.5	25.3	—4.6 Corrected.

Time, 14 min., 24⅔ sec.

Weight, 170 lbs.

Quality {98.5
99.4

Ratio of absolute pressures, .56.

TEST B. 1ST TRIAL.

Steam Pressure by Gauge. Initial.	Gauge on Orifice. Lbs.	Back Pressure. Inches Hg.
99	51	24.25
90	45	25.25
88	44	24.25
90.5	45.4	24.25
91.9 Average.	46.4	24,25
87.87 Corrected.	43.37	24.25

Time, 10 min., 56⅔ sec.

Weight, 160 lbs.

Quality, 97.8.

Ratio of initial pressure to orifice pressure = .57.

TEST B. 2D TRIAL.

Steam Pressure by Gauge. Initial.	Gauge on Orifice. Lbs.	Back Pressure. Inches Hg.
88	49.5	68
90	50	70
90	50	70
89	46.5	70
89.25 Average.	49.75	69.5
85.25 Corrected.	46.75	65

TABLE C.

Absolute Steam Pressure.	Absolute Pressure on Orifice.	Orif. Pres. / St. Pres.
34.7	14.7	.423
39.7	18.9	.476
44.7	20.9	.467
49.7	24.2	.487
54.7	27.2	.497
59.7	29.2	.489
64.7	32.4	.500
69.7	35.2	.505
74.7	40.4	.541
79.7	42.2	.529
84.7	45.2	.533
89.7	50.7	.565
94.7	52.7	.556

TABLE D.

Absolute Initial Pressure.	P. A.	Pounds Water Per Sec.
30.8	6.09	.0820
50.9	10.07	.1323
71.2	14.09	.1966
85.6	16.94	.2409
107.6	21.29	.3047
99.95	19.69	.2532
100.7	19.93	.2394
102.5	20.28	.2437

Area = .1979 sq. in.

PYROMETER EXPERIMENTS.

BY D. J. JENKINS AND F. PILLMORE.

The measurement of the temperatures existing in furnaces, becomes of great importance in connection with efficiency tests of steam boilers. What is required for this purpose is a pyrometer that can be handled with ease, and will give fairly reliable results. Pyrometers made by utilizing the expansion of two metals, will not give temperature determinations of value higher than 1000 F. They are liable to derangement, and do not give accurate determinations unless the whole stem of the instrument is uniformly heated, so they are of no value for the determination of high temperatures. The air thermometer, with porcelain bulb, has been successfully used for temperatures as high as 2000 F., but such thermometers are not of suitable form for determination of temperatures in a steam boiler furnace. The same objection holds to the electrical pyrometers, of which there are now in use two distinct kinds. The calorimetric methods of obtaining the temperature seem to be the only ones open for investigation, when seeking a simple method that can ordinarily be used. The metals that can be applied for this purpose are any with high melting points, and not easily oxydized by the furnace gases. Such metals are not easily found, as both platinum and iron are easily oxydized. The melting point of wrought iron is very high, but its specific heat is not so constant as platinum. The high cost of platinum is such as to preclude its use for such purposes, and the practical question turned on the accuracy of determinations to be made from wrought iron, cast iron or fire clay.

The following investigation, made by the writers, show that very uniform results can be secured, but that our knowledge of the specific heat of fire-clay will at present exclude the most promising of all materials for this purpose.

EXPERIMENTS WITH IRON BALL PYROMETERS.

The object of the experiment was the determination of high temperatures by means of the Iron Ball Pyrometer. The general method is to put a piece of metal into the fire, the temperature of which is desired, and after the metal has reached the temperature of the fire, to plunge it into a calorimeter filled with water. The specific heat of the iron being known, also the weight of the water in the calorimeter, the water equivalent of the calorimeter, and the temperature of the water in the calorimeter before and after the immersion of the heated iron; the temperature of the fire can be computed by means of the following formulæ;

$$(M+m)(\theta-t)=M'K(t'-\theta)$$

where $M=$ wt. of water, $m=$ water equivalent of the calorimeter, stirer, etc., t is initial temperature of water, θ is final temperature, M' is weight of iron, K is specific heat of iron, and t' is temperature of fire. The equation for mean specific heat between $o°$ *C.* and $t°$ *C.* is expressed by the following equation for wrought iron, as deduced from experiments of Mr. Holman, of the Massachusetts Institute of Technology.

$$K=.10687+.0000547\,t+.0000000428\,t^2$$

The experiments with wrought iron were worked up first, then as there were no data available showing the rate of change of specific heat of cast iron, a specific heat (.175) was assumed which would bring results in accordance with the data obtained from experiments. One series of experiments was made in which a piece of earthenware was employed as the heat carrier, the specfic heat of which was determined as accurately as possible by means of the Regnault apparatus in the Physical Laboratory. The average of our results showed the specific heat to be about 0.170. This number being used in computing the results of our experiment gave results higher than those obtained from wrought iron, the temperature of furnace being maintained as constant as possible. These results would seem to show that the specific heat taken for brick was too low; probably the specific heat of the brick varies with the temperature in the same manner as wrought iron.

The calorimeters used were the ordinary copper calorimeters in use in the Physical Laboratory, which were placed in an ordinary bucket and carefully wrapped in hair felting, which prevented to some extent any great loss from radiation. An effort was made in each experiment to have the temperature of the water in the calorimeter as much below the temperature of the room as the final temperature was above the temperature of the room. The loss of iron in each separate experiment from oxydation was the cause of some trouble; this was more noticeable in the experiments with wrought than cast iron. The effect of this, aside from the loss in weight, which was carefully corrected for in the latest experiments, was not very noticeable, as according to the tables of Clark the specific heat of $Fe_2 O_4$ is .165 and of $Fe_3 O_4$ is .172.

The results of the observations given on the following pages are tabulated in pairs, two determinations being taken at the same time.

ABSTRACT OF RESULTS OF DETERMINATIONS MADE TO DETERMINE TEMPERATURE OF FURNACE.

Wrought Iron Calorim.		*Cast Iron Calorimeter.*	
No. of Test.	Tempt. in Deg., Cent.	No. of Test.	Tempt. in Deg., Cent.
A	805	a	965.4
A	846	a	911.5
B	908	b	872.1
B	967	b	861.7
C	843	c	787.4
C	853	c	797.1
D	838	d	978.
D	825	d	961.
E	864	e	942.
E	883	e	959.
F	888	f	910.
F	908	f	931.
G	853	g	869.
G	854	g	914.
Average.	866	Average.	902.3

Fire Clay Calorimeter.	
No. of Test.	Tempt. in Deg., Cent.
a′	1130.6
a′	1158.3
b′	1146.2
b′	1239.4
c′	1229.8
c′	1296.8
d′	1249.6
d′	1205.6
e′	1274.6
e′	1198.0
Average.	1238.9

Determination of Specific Heat Fire Clay Brick.

Temp. of Steam, Deg., Cent.	Specific Heat.
95.8	.1677
98.2	.1739
96.2	.1700
Average.	0.1702

The conclusions to be drawn from this experiment are that the use of wrought iron or cast iron calorimeters affords a convenient and satisfactory means of measuring the temperature of the furnace. The possible error of a single determination from a calibrated instrument would not exceed 3 per cent.

SIBLEY COLLEGE PIN.

At a meeting on March 10, of Sibley Seniors and resident graduates, a selection was made of a pin to be worn by Sibley College graduates. The design is simple, being the stub end of a connecting rod, to be made of platinum and gold, and small enough to be worn as a scarf pin if desired. Out of a large number of designs presented by various jewelers, none seemed so popular as the one selected, which was presented by F. B. Corey, '92. As soon as rates can be secured, a maker will be selected, and pins ordered,—over forty students having already signified their intention of securing them.

HOLDING POWER OF LAG SCREWS.

BY R. T. MICKLE AND J. C. MC MYNN.

This test was suggested by the entire absence of any reliable data concerning the holding power of lag screws in the various kinds of wood used in the erection of buildings, machinery, and bridges as well as by inquiries from various manufacturing companies concerning the strength that such screws could be relied on to possess. These screws are used very extensively for millwright work, and also in railroading. The object in view is to procure some data which will be of practical value to those using lag screws. The test was carried on as follows: Lag screws varying in size from 1 inch to ¼ inch in diameter were procured from the —— Co. The samples received were of excellent workmanship.

The different kinds of wood used were White Pine, Norway Pine, Georgia Pine, Hemlock, and Oak. Tests were made with each size of lag screw, in each kind of wood and at depths varying from 1 inch to 6 inches. Holes were bored in the beams, equal in diameter to the diameter of the screw at the base of the thread and in depth an inch less than the depth to which the screw was to be sunk, *i. e.* for an ⅞ inch lag bolt, 4 inches deep, the hole bored was ⅝ inches in diameter and was 3 inches deep; this gave 1 inch of solid wood for the point to be imbedded in. The beams with the screws in them, were then placed in the Riehlé 100,000 pound testing machine, and the screws pulled out, care being taken to avoid bending.

In the accompanying table will be found the results of the tests. The samples of wood were such as would be found in practice, and any noticeable variation in the results may be accounted for by the presence of knots or seasoning cracks. In putting the screws in the different woods it was found that a dry unguent, as plumbago, was much preferable to oil, as the latter swelled the wood.

LAG SCREW TEST.

Diameters.		1 in.	7/8 in.	3/4 in.	5/8 in.	1/2 in.	7/16 in.	3/8 in.	5/16 in.	1/4 in.
White Pine.	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	400
	2	. . .	. . .	. . .	. . .	2150	2510	1240	1260	900
	3	3250	2700	3000	2800	3900	4200	1650	1970	. .
	4	4680	4400	3850	3800	5650	5000	2270	2500	. . .
	5	6100	5750	4890	4800	*7000	. . .	2900	2700	. . .
	6	7600	6000	5770	6000	. . .	. . .	. . .	. . .	. . .
Norway Pine.	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	800
	2	. . .	. . .	. . .	. . .	2000	2100	2050	1450	1200
	3	4700	3800	4400	3500	3250	2850	2640	2200	. . .
	4	5350	6500	6250	5000	4050	3600	3500	3100	. . .
	5	8000	7450	7300	6800	5600	4400	3550	. . .	. . .
	6	13000	9200	8800	8600	. . .	. . .	. . .	. . .	. . .
Georgia Pine.	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	630
	2	. . .	. . .	. . .	. . .	2660	2200	1820	1700	1670
	3	4180	3770	5300	4500	3830	3940	3000	2500	. . .
	4	6140	5600	6300	5790	5000	4490	3940	3200	. . .
	5	8440	7000	7560	6600	*6750	5600	*4880	. . .	. . .
	6	9440	8580	8300	8770	. . .	. . .	. . .	. . .	. . .
Hemlock.	1	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	550
	2	. . .	. . .	. . .	. . .	1570	1670	1300	1350	750
	3	2580	2700	2330	3360	2650	2230	2170	1530	. . .
	4	4590	4100	4740	4300	3850	3350	2840	2500	. . .
	5	6530	5620	6660	5500	4450	3400	. . .	. . .	. . .
	6	6900	6520	6700	6190	. . .	. . .	. . .	. . .	. . .
Oak.	1½	. . .	. . .	. . .	. . .	. . .	2120	1960	1800	940
	2½	5500	5900	5400	4900	3500	3500	3370	†3000	1860
	3½	8000	7500	7300	6880	4200	5200	4040	. . .	. . .
	4½	11100	9150	9200	8770	5200	5300	. . .	. . .	. . .
	5½	12470	13600	11500	9100	. . .	. . .	. . .	. . .	. . .

* Twisted off. † Broke in thread.

DIMENSIONS OF LAG SCREWS.

Diameter . .	1″	7/8″	3/4″	5/8″	1/2″	7/16″	3/8″	5/16″	1/4″
Diameter, bottom thread	23/32″	5/8″	9/16″	15/32″	28/64″	21/64″	17/64″	7/32″	5/32″
Pitch thread	4	4	4.5	5	5	7	7	9	10
Breaking strain	23000	18920	13450	11390	7300	5960	4460	2750	2600

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ADVANCED MECHANICAL LABORATORY WORK.

During the past term, in conjunction with the course in consulting engineering given by Professor Carpenter, various investigations have been conducted in the mechanical laboratory. Some of these are as yet uncompleted, but a few are presented in this issue of THE CRANK. These researches are all of great value as covering points not before investigated and providing data which it has heretofore been impossible to obtain.

THE NAVAL ENGINEER CORPS.

WASHINGTON, Feb. 24.—The House Naval Affairs Committee to-day ordered a favorable report on a bill providing that the reduction in the numbers of the Engineer Corps of the Navy provided for in the act of August 5, 1882, shall be considered as having ceased June 30, 1891. The passage of this bill would enable the corps to be increased, and would also make it possible for a number of officers to be promoted.

The above extract from the columns of the daily papers means that the appointment of a few engineers into the Navy Corps from civil life is probable, and it is possible that a number of Cornell men may apply for the purpose of securing a few years of service and that opportunity and leisure for professional improvement which naval life, more than any other, offers.

CURRENT EVENTS.

Sage Freshman Banquet March 3.

Washington Alumni banquetted Feb. 18.

Freshman Banquet at Clinton Hall Feb. 26.

Marston, '92 has been chosen captain of the crew.

The choice of the Hudson Intercollegiate Rowing Course, has been left to C. J. Shearn, '90.

Ex-President White and Dr. Schurman are at present lecturing at Leland Stanford University.

A new course in Gas Analysis, of special value to engineers, is presented by Professor Dennis.

Ex-President White, is prominently mentioned as a successor to Whitelaw Reid, as Minister to France.

The class of '92 has inaugurated the custom of having two class photographers. Those elected are Messrs. C. H. Howes and E. D. Evans.

Professor Albert W. Smith, '78, who is occupying the chair of machine designing in the University of Wisconsin, has been appointed Professor of Machinery and Machine Designing at Stanford University.

A careful estimate of the expenses of the Sibley College Inspection Tours has been made, and it is announced that the Eastern and Southern trips will cost $35 to $40, and the Southern trip for Marine Engineers $40 to $45.

First winter meet Feb. 20; second, March 4. Cornell records were broken as follows: Pole Vault, Jaquish, '93, 9 feet and 3¾ inches. Running High Kick, Murphy, '93, 9 feet and ¼ inches. The '88 memorial medal was awarded to Osgood for best all round athlete.

The Faculty of the University has been invited to send representatives to take part in the Tercentenary Festival of the University of Dublin, next Summer, and has accepted. It is not yet certain who will be asked to accept these positions Dr. Thurston has received a personal invitation from the University of Dublin for the same occasion, and is expected, if he should be able to go, to remain in Dublin as the guest of Dr. Lucius O. Hutton, of Fitzwilliam Place.

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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

PROGRESS IN MECHANICAL REFRIGERATION.

BY PROF. JOHN H. BARR.

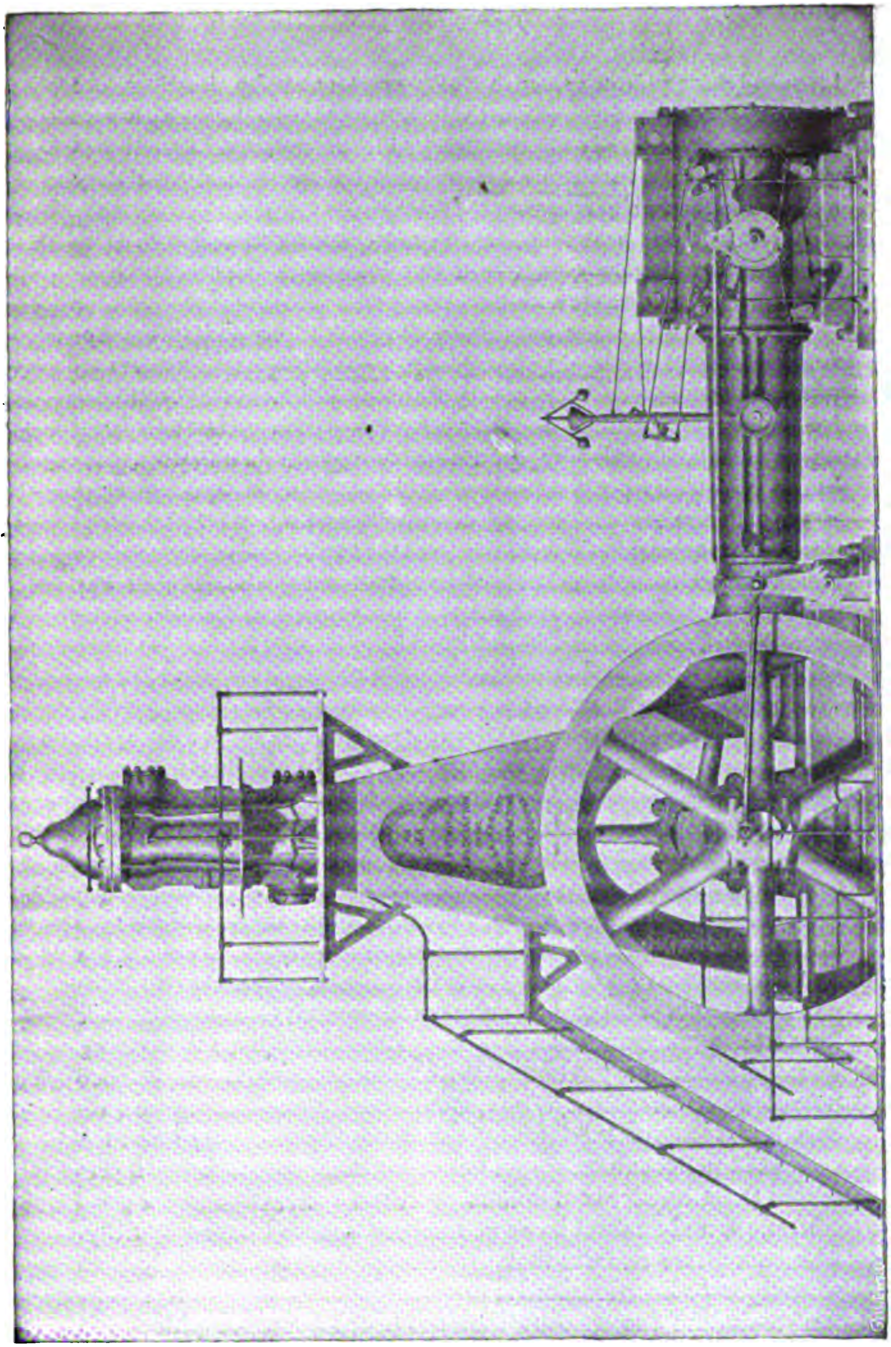
The October issue of THE CRANK contained a very clear and concise article on Mechanical Refrigeration and Ice Making by Mr. P. M. Chamberlain, '90. This specialty in mechanical engineering has developed in a very brief period to one of great and rapidly increasing importance. Probably nothing can offer more substantial evidence of this than the remarkable machine just completed by the De La Vergne Refrigerating Machine Co., of New York City. This machine has two double-acting gas compressors, 24 inches in diameter by 48 inches stroke; driven by a cross-compound Corliss engine (condensing) having cylinders of 32 inches and 64 inches diameter, with a stroke of 48 inches. The engine cylinders are horizontal while the compressor cylinders are vertical, being connected to the cranks upon which the engine acts. The machine is 28 feet 6 inches high, occupying a floor space of 37 feet 4 inches by 22 feet 3 inches. The crank shaft is 15½ inches in diameter, and it weighs 20,820 pounds. The two compressor connecting rods weigh 3400 pounds each, and the engine connecting rods weigh 3800 pounds each. Four and a quarter tons of phosphor bronze were used in the connecting rod and other bearings. The total weight of the machine, in the rough, was 195 tons, and finished weight is about 175 tons. The engine is rated at 600 horse power at 40 revolutions per minute, and the refrigerating machine is rated at 500 tons refrigerating capacity per 24 hours.

It may be proper to explain that such machines are rated in either of two units. The refrigerating capacity is expressed in terms of tons of ice melted to produce an equivalent cooling effect, while the ice making capacity is expressed by the number of tons of ice that the machine will make. When the machine is used for ice making, the water from which ice is to be made must be cooled from the natural temperature to the freezing temperature; as the ice produced is considerably below 32°, the incidental losses combined with this reduce the ice making capacity to about 0.6 the refrigerating capacity. As ice making is only one of the uses of these machines, and as the refrigerating unit is more definite, this is the one generally adopted.

The machine that has been briefly described is the largest which has ever been built, and it is interesting to make a few computations to give some idea of its enormous capacity. Five hundred tons of ice every day, would be melted in service equal to that which this machine is capable of performing. Now one ton of ice occupies about 36 cubic feet, and a house to store 500 tons of ice (if no waste from thawing occurred) would have to contain 18,000 cubic feet, equal to the capacity of a building 50 feet by 18 feet. As there is a considerable loss in storing ice, a house larger than this would be required for *each working day* in the year. The labor of handling this quantity of ice would be enormous and very expensive, to say nothing of the great inconvenience in its use.

A 600 horse power engine is used to drive this machine, and if 2½ pounds of coal, per horse power per hour, are allowed, which is liberal for this type of engine, we find that the coal consumption would be 18 tons per day; from which we conclude that the refrigerating capacity of 18 tons of coal is about equivalent to 500 tons of ice.

The most extensive use of refrigerating machines, at present, is in breweries, packing houses and cold storage houses, although they are used largely in chemical works, hotels and restaurants, as well as in artificial ice manufacturies. It is found that, even in some northern cities, the artificial ice can compete with the natural product, owing to regularity of the supply, and the fact that



THE LARGEST ICE MACHINE IN THE WORLD.

large ice storage houses, with their great waste by thawing, are avoided. It is evident, then, that for refrigerating service, where the formation of ice is not necessary, the mechanical method has great advantages in cleanliness, economy of space, and regularity and control of refrigeration.

It is altogether probable that the refrigerating machine will become more and more common in the industries where it has already been introduced, and that many new fields will be open for it. Theatres and other public buildings will be generally supplied with cool fresh air in summer, using the same system of pipes and fans that heat and ventilate in the winter. Artificial ice, made from distilled and filtered water, will drive out to a large extent, the less wholesome natural product, with its unnatural pollution. Possibly our domestic refrigerator will be connected by pipes with the central station, avoiding the dampness and general annoyance unavoidable with the present method of using ice. Is it difficult to believe that the ice box will share the fate, in our advancing civilization, of the kerosene lamp, and the old fashioned stove?

REPORT OF THE ASSOCIATE ALUMNI.

The regular annual meeting of the Associated Alumni of the University took place during Commencement week, in June last, and the report of the proceedings, including reports of its committees, have recently been printed and distributed. It contains some interesting and some very suggestive information. Out of 1500 alumni or more, 56 attended the meeting—largely from Ithaca and the adjacent portions of New York State. The Treasurer reported receipts of $43; balance carried over, $154.61; expended, $151 94; balance on hand, $54.67. The committee endeavoring to raise funds for "Alumni Hall," and to secure the $10,000 offered by ex-President White, conditionally on their success, report but $3,000 subscribed by the 1500 alumni; only one in a dozen of the list subscribing a dollar for the institution which presented them hundreds of dollars' worth of instruction and a good education, and enabled some of their number to become wealthy. The committee remark that the subscriptions come mainly from alumni *least able*, pecuniarily, to assume such responsibility. The well-to-do and the wealthy were not heard from. A pitiful and suggestive showing. The committee further remark that, on such a showing, it seems doubtful whether it is wise to press the matter further, or until some stronger feeling of regard and patriotism toward the common Alma Mater arises. Mr. Robert H. Treman was elected Alumni Trustee for five years.

The report of the Alumni Trustee, Mr. W. C. Kerr, was read and is printed in full. Its most interesting portion is that referring to the growth of the technical departments of the University. Mr. Kerr reports that "one slight cloud" has arisen during the past year: "The enormous growth of the technical departments, notably mechanical and electrical engineering, has conduced to the impression that Cornell is a great and growing technical school; while the interests of general education are being somewhat sacrificed to this end. This has caused the fear, both within and without the University, that the technical courses so overshadow the general as to cause serious harm to the latter, and has led to the suggestion that greater effort be made to build up the liberal courses to the highest degree of prosperity before further encouragement is given to technical lines." Mr. Kerr goes on to present a most appreciative statement of the value of the "liberal" side of the University to the institution itself and to the technical side as well, and also of the liberalizing influence of the technical departments upon the purely educational.

He does not say that, in an institution founded for the especial purpose of promoting the departments of industrial education and professional instruction, this accomplishment of its prescribed "leading object" should be a matter of the highest gratification to every alumnus, and to every friend of Cornell and the policy which its foundation represented, of real congratulation, that the main purpose of Mr. Cornell himself, throughout his life and in every moment of the history of the University up to the day of his death, should be accomplished; but he does say that "It would never do to trim the heaviest fruit-bearing branches merely for symmetry." He goes on to show that the general courses are favored as the almost exclusive recipients of the benefits of the five hundred and odd state scholarships, and the fellowships, and as requiring a much smaller tuition fee; while the Sibley College courses, for example, in spite of these discriminations of immensely greater cost of instruction, and their much more engrossing and arduous work, are far in the lead; so much so, in fact, that he concludes that it would be profitless to attempt further discrimination against them. "Cornell will never become a great trade school, nor, on the other hand, will her technical departments ever be voluntarily stunted; and in this, as in other pioneering that has been done at Cornell, the final result will be acceptable to all."

It is an interesting study to any one specially concerned in the great work which Cornell University and the other "Land Grant Colleges" of the country were founded to establish and to carry on, to see how persistently and consistently and continuously the sentiment above mentioned as constituting a "cloud" in Cornell's sky has stood before the Founders and the Trustees, endeavoring to do their duty as prescribed by law and charter, and has confronted a Faculty seeking, honestly and dutifully, to promote that great work which the legislatures and Mr. Cornell so gloriously took up. The legend at the head of our columns fails to catch the eye, or to impress itself upon the mind, of even many alumni of Cornell; notwithstanding the evidence that it is the endeavor to carry on the prescribed innovation in educational work that has done so much to give the University that life and fruitfulness of result that distinguishes her and her progeny among later colleges. That legend is one of the most clearly written signs and sentiments of the time. When it is forgotten at Cornell, it will mean failure of her great purpose, treason to her duty to the country and the people, and the slipping of the institution out of sight into the great crowd of institutions mouldering in methods suited only to the days of the cloister. But while every real friend of the University and of its great purpose, deprecates a halt because of that "cloud;" no real friend of Cornell can fail to see and to acknowledge, to assert, that the prosperity of the liberal courses must always be a vitally important element in the promotion of not only her prosperity and reputation, but even of her prescribed "leading objects," the first duty of Trustees and Faculty, alumni and student alike. No great advance of recent years has given greater cause for congratulation, on all sides, than the founding of the new School of Philosophy; and no true friend of the University, and its first and highest task, can fail to see that the steady and solid advances of its classical and other liberal courses have been, and must always be, vital elements of complete success, and that their growth is a matter of most sincere rejoicing on the part of all.

Regarding finances, we observe that the report shows the receipts of the University to have been $360,000 from investments, $90,000 arrearages from the state, (which has never aided the University, but has always refused to do its part in the erection of buildings and provision of equipment contemplated in the agreement with the general government, and has until now withheld even a part of the legal income from funds in its treasury,) $200,000 by gift of Mr. Henry W. Sage, and $200,000 from the bequest of Mr. Fayerweather; while the United States govornment has provided additional annual income, amounting to $15,000 the first year, and increasing annually for ten years to $25,000 per annum afterwards. The money from the state goes into the Law School building; that from Mr. Sage covers a part of the costs of sustaining the new School of Philosophy; the Department of Agriculture is to have an $80,000 building, and the Gymnasium receives $23,000 for additions. We do not find that the technical departments most needing accommodations and equipment are provided for from these accessions. The additions to income for the "leading object" of the University, given by the general government, actually relieve the University treasury of costs of their operation, to that extent, and thus enable it to carry other departments. There is no indication that they directly aid the departments for which they were provided, much as those departments need assistance. The final deduction from the facts revealed by this report seems to be that the technical departments are growing vigorously, in spite of every obstacle, natural or artificial, by which they are handicapped, and that the great gifts of the nation and of Ezra Cornell are doing much in the promotion of other than the purposes for which they were primarily and especially intended—all of which means, whatever else, gain of glory and prosperity to Cornell, and continuously increasing opportunities for good. We may add that it all points to the desirability of finding more friends of her grandest purpose, and steadier support of that splendid work. Her most seriously strangled departments are, principally, those for the promotion of which her charter was drawn, her foundations were laid, and her founders most earnestly labored. Meantime, the University prospers in all departments, and her principal embarrassments come of her magnificent opportunities. When she finds a few more public-spirited and wealthy friends to take up that work of development where it is most needed, and where her opportunities are grandest, she will make a still more splendid progress and still more completely fulfil the purposes and ambitions of her founders, while making more famous the names of both the older and the newer benefactors; not the least of whom will be he who is to establish and give his name to the great Laboratory of Experimental Engineering, now all ready, opportunity offering, to break its chrysalis shell.

DIMENSIONS OF THE SIBLEY COLUMBIAN ENGINE.

The detail drawings for the engine to be built in the Sibley College shops during the present year are nearly completed, and the patterns are in process of construction. Work will soon be commenced in the shops, in fact some of the special tools required are already constructed. The drawings of the engine, and details of design, are due to Messrs. R. T. Mickle, J. Kuhn and D. J. Jenkins, the drawings of the condenser and air pump to Messrs. J. C. McMynn and W. G. Starkweather.

The engine will be a vertical engine, triple expansion, arranged so that the engines can be run as simple, compound or triple expansion, in any possible combination. Any engine can be run as a simple engine with one hundred pounds pressure if desired. Regulation will be accomplished by governors on the fly wheels, and each engine will have four valves of the Corliss type, controlled by this governor. The engine will be complete in itself and after the exhibition will form a valuable experimental engine for the laboratory. The dimensions of the various parts of the engine are as follows:

Diameter of the high pressure cylinder, 7 inches.
" " intermediate pressure cylinder, 10 inches.
" " low pressure cylinder, 17 inches.
Length of stroke, 16 inches.
Boiler pressure, 150 lbs.
Revolutions per minute, 190.
Estimated horse-power, 120.
High pressure cylinder running as single engine:
Boiler pressure, 150 lbs.; estimated horse-power, 63.
Intermediate pressure cylinder running as single engine:
Boiler pressure, 100 lbs.; estimated horse-power, 72.
Low pressure cylinder running as single cylinder engine:
Boiler pressure, 100 lbs.; estimated horse-power, 150.

Main bearing:
High pressure, 4"x6" long.
Intermediate pres., 4½"x7" long.
Low pressure, 6"x9" long.

Crosshead pins:
High pressure, 2¾"x3½" long.
Intermediate pres., 3"x3¾" long.
Low pressure, 4"x5" long.

Crank pins:
High pressure, 3½"x4" long.
Intermed'te pres., 3½"x4½" long.
Low pressure, 5"x6" long.

Weight of flywheel, 1800 pounds.
Length over all, 16 feet.
Width " 7 feet 6 inches.
Height " 9 feet.

All cylinders jacketed, as well as heads.

TEST OF FIRE PROOFING MATERIAL.

BY PROF. R. C. CARPENTER.

In the construction of fire-proof buildings the iron columns and beams, which are used to support the structure, are enclosed in some non-conducting material,—usually fire-clay, in the form of brick or slabs. Other materials are being used instead of fire-clay, and a resent test was made, in the Sibley College Laboratories, of a new material termed mackolite, which is manufactured by the Mackolite Plaster Board Co., of Chicago. The test was made in comparison with a fire-clay slab of the same thickness. The specific gravity of the mackolite was determined, and found to be 0.749, water being 1.00.

The method of test was as follows: Over an ordinary portable forge, a sort of oven of brick was built. This oven consisted of three chambers, in the lower one a coke fire was built; the roof of this chamber was formed of the materials to be tested, one-half being a slab of firebrick, the other half a slab of mackolite. By means of a partition of fire-brick placed over the joint between the two materials, two air chambers were formed, which were heated up by the fire underneath. Thermometers were inserted in each chamber and the rise in temperature noted. By this means the comparative value of the non-conducting materials was obtained. The conditions of fire, being kept as nearly the same under the two materials as is possible, the temperature below the two materials would be practically the same in each case.

Two tests were made, the first test being made with slabs ¾″ thick, and the second with slabs 1.4″ thick. In the first test it is seen that the ratio of temperatures is about 3 : 1 in favor of the new material. In the second case, another quality of fire-brick was used, the temperatures being about 50° in favor of mackolite. In the observations which are given in a tabulated form on the next page, it is seen that in the chamber above the mackolite, at the end of two hours, the temperature was below the boiling point of water, while at the same time the chamber above the fire-brick was 562°. In the longer test made with very thick materials the difference was not so great; at the end of two hours, the temperature in the chamber above the mackolite was 224°, above the fire clay 266°. At the end of 4½ hours the temperature above the mackolite was 340° or about the same as steam at 100 pounds gauge pressure.

At the close of both the tests, it was found that the new material was badly cracked and broken by the heat, the fire-brick remaining uninjured. As a non-conductor, it is seen that the mackolite is much superior to the brick.

The following are the results of the test made by D. J. Jenkins and H. G. Hamann :

No. I—Thin Slab.			No. II—Thick Slab.		
Time.	Chamber above Fire-brick.	Chamber above Mackolite.	Time.	Chamber above Fire-brick.	Chamber above Mackolite.
3.10	174°	67°	10.35	134°	103°
.15	210°	72°	.45	146°	110°
.20	242°	79°	.55	157°	112°
.25	250°	85°	11.05	174°	125°
.30	270°	93°	.15	187°	134°
.35	283°	96°	.25	198°	141°
.40	292°	103°	.35	212°	148°
.45	304°	106°	.45	226°	157°
.50	320°	111°	.55	235°	163°
.55	328°	112°	12.05	246°	182°
4.	340°	114°	.17	258°	218°
.05	348°	123°	.25	264°	220°
.10	362°	128°	.35	266°	224°
.15	367°	130°	1.25	282°	226°
.30	402°	144°	.35	300°	240°
.35	426°	150°	.50	316°	248°
.40	438°	156°	2.	325°	256°
.45	476°	163°	.05	335°	269°
5.	516°	172°	.20	350°	282°
.05	540°	176°	.35	360°	293°
.10	562°	180°	2.45	375°	312°
.15	600°	184°	3.	382°	340°

The value of such materials in protecting beams in a building from the effect of heat is well shown. In this case the temperature in the coke fire was probably 2000° F. This fire played directly on the material, and yet at the end of a period of time equal nearly to five hours, the temperature, directly above the material, did not exceed that of high pressure steam. Even had the temperature reached the higher limit of 600° F., it would still be too low to injuriously affect the strength of iron. Indeed the experiments made at the U. S. Arsenal on the effect of heat on iron would seem to indicate, that the strength increases with rise of temperature to about 600 F. then it decreases with rise of temperature to about one-fifth its usual strength at 1600° F. This experiment shows that the protection afforded by such a covering might be sufficient to make an iron girder withstand the heat from the hottest fire.

THE VALUE OF GRAVITY IN THE BASEMENT OF THE PHYSICAL LABORATORY.

BY JOHN S. SHEARER.

A few years ago a series of long and careful experiments was carried on by Mr. Pierce, of the United States Coast and Geodetic Survey, for the purpose of determining the force of gravity in the basement of Franklin Hall. The result obtained from his data was communicated to Professor Nichols in the following letter:

U. S. COAST AND GEODETIC SURVEY OFFICE,
WASHINGTON, July 21, 1890.

Prof. E. L. Nichols, Cornell University, Ithaca, N. Y.:

DEAR SIR—The delay in furnishing the information asked for in your letter of the 27th ult., was due to the fact that it was necessary to communicate with Assistant C. S. Pierce. The value of the force of gravity at Cornell, as derived from material in course of preparation for publication, is 980.274 dynes, and this is believed to be very nearly if not quite correct.

Respectfully yours,
T. C. MENDENHALL, Sup't.

Meanwhile Mr. F. J. Rogers had made a determination, using the Kater pendulum method. · The pendulum used consisted of a steel bar about one and one-fourth metres in length, and having two adjustable knife edges inserted a short distance from the ends. Two weights of like dimensions and form, but one of which was hollow, were adjusted between the knife edges and the ends of the bar. Thus the resistance of the air was practically the same from whichever end the pendulum swung. By means of a small plane mirror affixed to the middle of the bar, the knife edges were made as nearly parallel as possible. When the plane of the mirror was perpendicular to the knife edge, from which the pendulum was swinging, the image of a fixed object would remain fixed. The weights were then adjusted until the time of vibration was as nearly as possible the same about each knife edge. The time was measured by a chronograph, that registered also the beats of the standard clock. Connection with the chronograph was made by a small pointer, which touched a drop of mercury at each vibration. The distances between the knife edges were carefully measured on the comparator, using a "standard" meter bar as accurate. Mr. Rogers used the formula,

$$\frac{\Pi^2}{g} = \frac{t^2 + t'^2}{2(h + h')} + \frac{t^2 - t'^2}{2(h - h')}$$

where h and h' are the distances of the center of gravity of the pendulum from the knife edges, k, k', and t, t', are the corresponding times of vibration. Since $h + h'$ is accurately known, and $h - h'$ is relatively large compared with $t^2 - t'^2$, the second term is very small. Corrections must be made for difference in temperature when time was taken and when the bar was measured.

Mr. Rogers' determination gave $g = 980.3129$ dynes. Last fall the experiment was repeated by the writer, and the computation was based on the formula,

$$T = \Pi\sqrt{\frac{L}{g}}\left\{1 + \frac{1}{4}\sin^2\frac{a}{2} + \cdots\cdots\right\}$$

where $T =$ time of vibration, $L =$ distance between knife edges, and $a = \frac{1}{2}$ angle of vibration. The result obtained was $g = 980.295$ dynes.

Physical Laboratory of Cornell University,
April 13, 1892.

A COMPUTATION OF JOULE'S EQUIVALENT.*

BY DR. R. H. THURSTON.

Some years ago, the late Dr. Pliny E. Chase, then of Haverford College, published in the *Journal of the Franklin Institute* a series of articles of singular interest, and of curious result, in which he often traced what he called certain harmonies of nature, exhibiting some strangely related or oddly coincident physical laws and constants, and in which he deduced a number of remarkable conclusions. He subsequently published a short paper, reprinted in the *Philosophical Magazine*, in which he showed some reason for anticipating that it might ultimately prove that the value of γ, the ratio of specific heats of gases, is simply the numerical quantity

$$1 + \frac{4}{\pi_2} = 1{\cdot}405285$$

(*Phil. Mag.*, 1885, p. 520.)

It occurred to the writer to compute the value of J, the mechanical equivalent of heat, from this assumed value of γ, taking the

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*From the *Journal of the Franklin Institute*, April, 1892.

best values of constants determined by Regnault, referring all quantities to the air thermometer, and taking air as the gas to which the constants so selected should appertain.

From the well-known equations deduced by both Rankine and Clausius, we have the equality,

$$C_p - C_v = R = \frac{p_0 v_0}{T_0}$$

or the difference between the two specific heats is constant, a fact first pointed out by Carnot, and later proved by the modern methods of thermodynamics by the founders of that science.

Since we take

$$\frac{C_p}{C_v} = \gamma$$

we have

$$C_p = J c_p = \frac{\gamma}{\gamma - 1} R ; J = \frac{\gamma}{\gamma - 1} \cdot \frac{R}{c_p}$$

and taking as Regnault's most probable values of *C* and of *R*, in British measures, 53·37 and 0·2375, we have

$$J = \frac{1{\cdot}405285}{{\cdot}405285} \cdot \frac{53{\cdot}37}{0{\cdot}2375} = 778{\cdot}12$$

in foot pounds, or 427 kilogrammetres per calorie. This corresponds to about 775 on the mercurial thermometer, falls within about one-eighth of one per cent. of the value assigned to *J*, by the British Association Committee of 1876, and is somewhat lower than the figures obtained at the temperature of maximum density of water by Rowland in 1880. This determination would seem to lend some color of probability to the conjecture—for it seems to have been little more—of Dr. Chase. In further, and perhaps more satisfactory, confirmation of this, as at least a closely approximate value, as have the work of Dr. Röntgen, who, in 1872, obtained $\gamma = 1{\cdot}4053$, as a mean of ten best observations. (*Pogg. Ann.*, 1873, s. 580.) Probably the most uncertain datum involved in this computation is the value of *R*; but it is probable that all these figures are very accurate and the computed value of *J* must be correspondingly so. Further examination of the value of *R*, which involves the location of the absolute zero, is desirable, however.

THE EFFECT OF THE INERTIA OF INDICATOR DRUMS.

BY MESSRS. HOLBROOK, ALDRICH, AND ELY.

Indicator drums revolve in a harmonic motion if the inertia of the mass be neglected, and the speed of rotation is then greatest at the half stroke of the piston. Therefore, if the drum spring tension can be adjusted so as to exactly counterbalance the effect of the inertia of the moving parts, the theoretical harmonic motion will be nearly realized.

In most indicator drum springs the tension increases directly in proportion to the extension. Since the speed of the drum is greatest at one-half stroke, at this point the drum will run ahead of its theoretic motion if the spring tension is not sufficient to counteract the effect of the inertia of the moving parts. Therefore if the tension of the drum spring is adjusted to exactly balance the effect of inertia at half stroke, the card should be as nearly as possible theoretically correct. To obtain the value of this tension, use was made of the formulae for the harmonic motion of a body.

$t =$ time of ½ length of card = ¼ of a revolution.

$s =$ ½ length of card.

$t = \frac{\pi}{2\sqrt{a}}$ (See Church's Mechanics.)

$P = pM = T$; where T is the tension in the spring at ½ the length of the card.

$p = -sa \quad a = -\frac{p}{s} \quad M = \frac{W}{g}$ = mass of rotating parts. $a = -\frac{T}{Ms}$

$$\therefore t = -\frac{\pi}{2\sqrt{\frac{T}{Ms}}}$$

$$t^2 = \frac{\pi^2}{4\left(\frac{T}{Ms}\right)} \qquad T = \frac{\pi^2 Ms}{4t^2}$$

The foot, pound, and second system were used in the formulae. The results are shown in the following table.

TABLE FOR TENSION ON INDICATOR DRUM OF 0.01 LBS. WEIGHT.

Revolutions Per Minute.	Pounds of Force to Pull Drum 1.75 in.	Revolutions Per Minute.	Pounds of Force to Pull Drum 1.75 in.
50	0.0010	225	0.025
75	0.0025	250	0.0315
100	0.0050	275	0.038
125	0.008	300	0.0455
150	0.0115	350	0.0615
175	0.0155	375	0.07
200	0.02	400	0.08

WEIGHT OF INDICATOR DRUMS.

*Crosby,	.32 Lbs.	Thompson,	.66 Lbs.
New Tabor,	.84 "	Calkins,	.42 "

The following indicators were tested: the Crosby, New Tabor, and Calkins. The Brown drum spring testing motion was used to obtain the cross-head motion, and the indicator was connected with German silver wire, as it was found by experiment that the best cord introduced a relatively large error. In all cases the cards taken were slightly longer than those made when the crank was turned over slowly by hand, the error occurring when the crank was farthest from the center and therefore taking place during the expansion part of the card for the head end and during admission at the crank end of the cylinder. In the Crosby and Calkins springs the resistance increased proportionally to the extension, while the New Tabor gave a nearly constant tension.

The table appended gives the per cent. by which the cards at the given speeds exceeded the true length.

	Revolutions per minute.	Error in per cent.
Crosby,	175 325	+0.5 +0.9
Calkins,	250	+0.8
New Tabor,	240	+1.5

---

*In the case of the Crosby, only one-half the weight of the drum spring was included.

FLUCTUATIONS OF THE "ZERO POINT" OF A SENSITIVE GALVANOMETER.

BY F. J. ROGERS, M.S.

The sensitiveness of a galvanometer with a single needle varies inversely as the strength of the magnetic field in which the needle moves. Therefore, in order to render such a galvanometer very sensitive, it is only necessary to make the magnetic field very weak. This is accomplished by so placing a regulating magnet that its field almost neutralizes the earth's magnetic field at the point where the needle moves. Anyone who has used a galvanometer made sensitive in this way knows how the position of equilibrium or the "open circuit zero point," shifts along the scale from hour to hour. On some days with a very sensitive galvanometer this variation from *moment to moment* is so great as to entirely mask the effects to be measured. The writer, having been considerably inconvenienced by this shifting of the "zero point," thought it worth while to make a study of the matter.

This phenomenon is obviously due to a variation of the magnetic field in the vicinity of the galvanometer needle, as there is no other variable factor. If the magnetic moment of the regulating magnet be constant, as is usually the case, and if there be no local magnetic disturbances, this variation must be due to a variation in the earth's magnetic elements. A reflecting galvanometer with a single needle was set up where the local magnetic disturbances were thought to be negligible, and made sensitive as above described. The position of equilibrium or "zero point" was then observed by means of a telescope and scale, for about every half hour during the day for three days. Curves A, B, and C, (Fig. 1) show the relation between the position of the "zero point" and time. Abcissae represent times and ordinates the corresponding value of the "zero point." Beginning at about the same point at 8 a. m. each day, the "zero point" moved up the scale until 1 p. m., when it reached a maximum indicating a maximum *westerly* declination of the needle. From this time until evening the "zero point" dropped down the scale and reached its original starting point on the next morning. The needle of another galvanometer in a different part of the building passed through a similar cycle. The motion, however, was not always in the same direction as in the first instrument. This is undoubtedly accounted for on the score of local influence

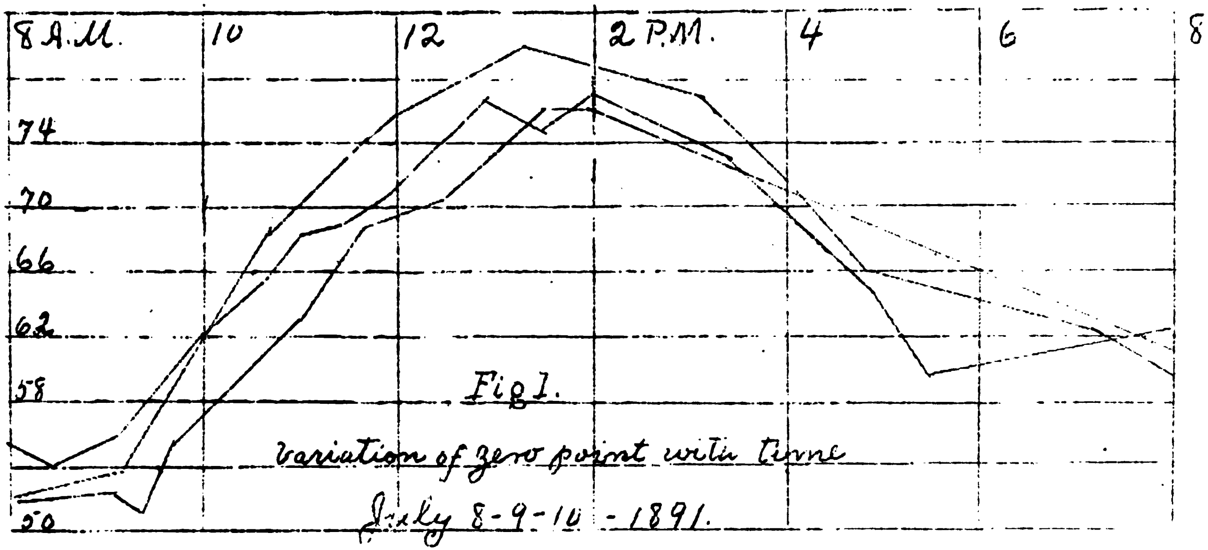

Fig 1.

Variation of zero point with time

July 8-9-10 - 1891.

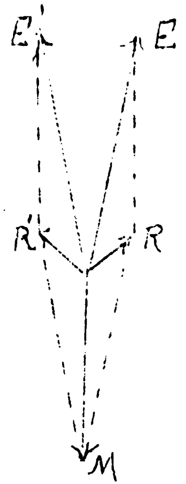

Fig 2.

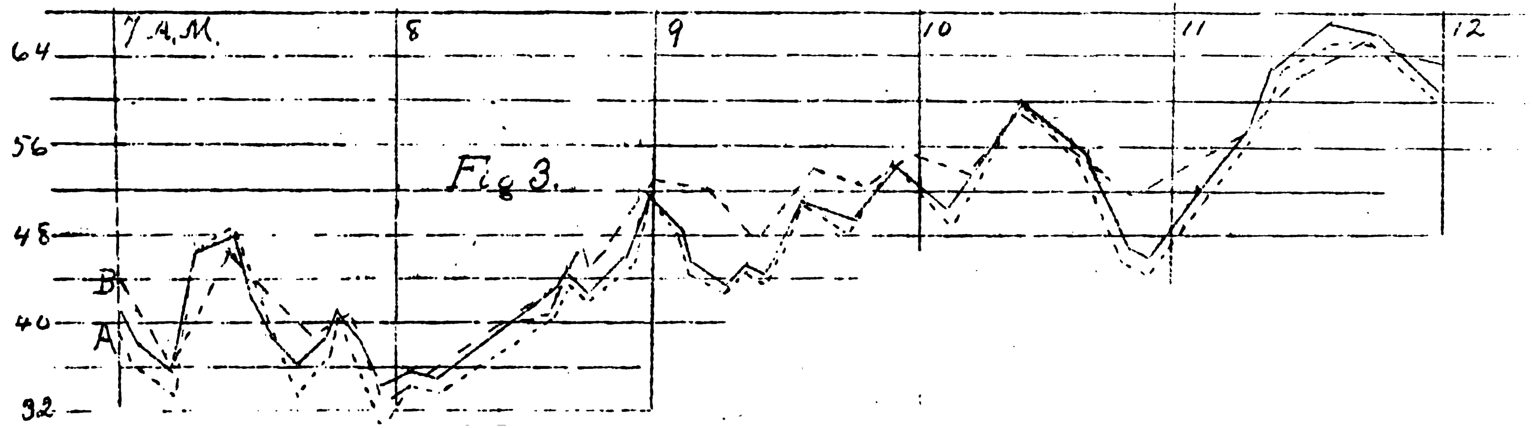

Fig 3.

as the second galvanometer was not more than 30 feet from a series motor and its zero point was noticed to vary considerably when the current was turned on or off the motor.

The cycle of motions through which the galvanometer needle passed is the same as the diurnal variation of the earth's magnetic declination. However, the diurnal variation in declination is only 20′ or 30′ while the galvanometer needle moved through 10°, or 25 times as much. Nevertheless it seemed highly probable that the phenomenon studied was due to this cause. To test this theory another galvanometer was set up about ten feet from the first one but its needle was suspended in the earth's field, *not* in a weakened field. It then acted merely as a declination needle. The "zero points" of the two galvanometers were observed every 15 or 20 minutes for 9 hours. When the curves for the two needles were platted, as above described, it was found that the curve for the first one in the weakened field was almost an exact copy of the curve for the other galvanometer needle used as a declination needle, except that the ordinates of the former were about 20 times greater than the corresponding ordinates of the latter. That is the needle in the former case moved over an arc of 10° while in the latter case the arc was only .5°.

To explain how the needle in the weakened field *magnifies* the motion of the declination needle: let O E (Fig. 2) represent in length and direction the horizontal intensity of the earth's magnetism and O M represent the same quantities for the magnetic field of the regulating magnet in the vicinity of the galvanometer needle. In this case O R will represent in length and direction the resulting magnetic field, consequently the magnetic axis of the needle will be along the line O R. Now if in any time, t, the direction of the earth's field varies from O E to O E′, the direction of the resultant field will vary from O R to O R′. From this it is obvious that if O M is very nearly equal to O E, then if O E moves through a very small angle, O R, and consequently the direction of the galvanometer needle will move through a very much greater angle.

In order to determine to what extent the shifting of the "zero point" is dependent on the variation in magnetic declination, the "zero points" of the two galvanometers above spoken of, the one with the needle in the weakened field and the other in the earth's field, were read every *few minutes* from 7 a. m. until 10 p. m., July 17, 1891, In Fig. 3 are given the curves showing the variation of "zero points" with time for the two galvanometers. The full curve corresponds to the galvanometer in the weakened field, (whose horizontal intensity was $\frac{1}{24}$ that of the earth's field), the dotted curve A to the one in the earth's field; but in the latter case the ordinates are on a scale twenty-five times greater than in the former case. The dotted curve, B, represents the variation in magnetic declination for the same day as obtained from the continuous recording declination needle at Washington, D. C. The ordinates in this last curve are on a scale about forty times greater than the corresponding ordinates of the full curve. These curves prove beyond question that, local influences aside, the fluctuations of the "zero point" of a sensitive galvanometer are almost wholly due to variations in magnetic declination. It is further evident that changes in declination are almost identical at widely sepatated points and consequently that the "zero points" of galvanometers all over the country simultaneously pass through the same cycle of variations.

In this connection it should be added that the irregular changes in declination were on July 17 much greater than usual. Also on this day as well as on most days the magnetic disturbances were much greater in the forenoon than in the afternoon.

In the three cases in which the motions of the *two* galvanometer needles were observed it became, in the afternoon, more and more apparent that there was some other cause for the variation of the "zero point" besides the changes in declination. The needle still copied the motions of the declination needle but its axis was generally more nearly in line with the declination needle than would have been expected from its motions in the forenoon. This is readily accounted for by the fact that the horizontal intensity of the earth's magnetism is also subject to a diurnal change, which reaches a maximum about 10 p. m. In Fig. 2 this would be represented by an increase in length of O E during the afternoon. The consequence of this would be that O R, the resultant field, would make a less angle with O E than would otherwise be the case. This is exactly what was observed. The inconvenience due to the shifting of the "zero point" may be avoided in three ways, (1) By working in the afternoon when magnetic disturbannes are least; (2). By neutralizing the earth's field by means of a wrought iron case about the galvanometer as in Thomson's "ironclad" or marine galvanometer, and (3), by using an "astatic pair." In this latter case no regulating magnet need be used and the "zero point" varies very little.

Physical Laboratory of Cornell University, 1892.

NOTE ON THE PRACTICAL MANAGEMENT OF LOCOMOTIVES.

BY J. ESREY JOHNSON, JR., M.E.

The point which the writer wishes to bring out, relates to the proper course to be pursued when a great deal of water is being carried over from the boiler, either in consequence of too much water in the boiler, or the presence of grease, or any other cause which produces priming. In all of that class of engines in which the power developed by the engine is controlled partly by the throttle and partly by the position of the link which drives the single slide valve, it is customary to run the engine with the throttle wide open and the "links hooked up" as far as the requirements of the power demanded will allow,—generally to a position in which cut-off takes place at from one-fourth to one-half the stroke. In that case the amount of compression varies with the degree of expansion which in positions between these limits is considerable. If now a large amount of water be introduced into the cylinder with the live steam, the cylinder will remain wet throughout the stroke and in the exhaust there will generally be a greater proportion of water than in the live steam, so that when compression begins there is not only steam in the cylinder but a considerable amount of water as well. It may readily be seen that if the proportion of water be very great, or the amount of compression large, a sufficient quantity of water may be entrapped by the closing of the exhaust valve to more than fill the clearances spaces with the result that the valve will be lifted from its seat, or the piston, or cylinder heads broken. It is not generally possible to stop and blow off some of the water in the boiler, but if the links be dropped down as far as they will go and the power regulated by the throttle the chances of accident are reduced in three distinct ways, as follows: The portion of the stroke during which the exhaust remains open is considerably increased, and the quantity of steam and water remaining in the cylinder when the exhaust closes, to be compressed into the clearance spaces, is reduced to a small fraction of its former amount. The result is that the liability of the volume of water so entrapped to be greater than the clearance volume is diminished in the same ratio.

The superheating on account of the wiredrawing at the throttle partially dries the steam, the superheat being expended in evaporating a part of the entrained moisture. The quantity of steam used is greater when it is throttled than when it is used expansively without throttling, and the water is therefore more rapidly brought down to its proper level and normal conditions restored, if the trouble comes from having too much water in the boiler, as it generally does. It is of course much the best way to watch the gauge cocks and not get too much water in the boiler, but as priming does occasionally occur to a dangerous extent from this and other causes, a practical and promptly available safeguard is a great desideratum and, as partly supplying this want, this suggestion is offered.

SIBLEY COLLEGE MORTALITY REPORT.

The report of the Dean to the Faculty, made on the 4th of March, shows that the list of students suspended, in consequence of having fallen too far behind in their work to go on with their classes, includes about three per cent. of the whole student body of the University. This is a small proportion, but is much larger than last year, when it was just one-half as great. The severity of the Sibley College courses is well exhibited by the fact that its proportion was above that of the University as a whole, and much above the figures of the "general" courses. The college lost five per cent., a small figure for a technical school, but large as compared with most other departments of the University. In other departments, Architecture suffered most, with a loss of eight per cent.; Civil Engineering lost but two per cent., and only six students were dropped out of all the other courses together. This is the extraordinary feature of the reports of both this year and last. Such high scholarship—or such easy work—is most remarkable. By classes, one-third were dropped from the Freshman class, a very low figure; one-third were upper classmen, registered back as Freshmen, and nearly one-third were Sophomores, usually so registered. The Junior class lost one man, and the Senior two.

The deduction of the Dean of the University is that "the most satisfactory progress in University work is done by those who have entered with 'Regent's Diplomas,' which indicate a long period of preparatory study." It is agreed, on all sides, that thorough preparation is the essential preliminary to successful work at Cornell; and this is obviously especially true of the Sibley College courses. It is also evident that students make a mistake who enter these courses because of their popularity, and without special fitness for them. The occasional, increasingly frequent, change of students who have thus erred, into the other, and especially the "general" courses, shows that this error is sometimes recognized before it is too late; but there are still too many men in the College, unfitted for its work, and better prepared for business, law, medicine, or the ministry, than for engineering. Even the greater difficulty and longer working hours of the Sibley College courses, and the higher prices for tuition, and extra costs for expensive shop and laboratory instruction, not only fail to keep down the number of applicants well-fitted by training and by natural talent for the profession of engineering, but even fail to repel some who can not expect to succeed in the profession, lacking the natural genius for it, however well prepared they may apparently be. The details of the records of dropped students show that no man weak in mathematics,—including descriptive geometry,—or lacking mechanical talent and fondness for the physical sciences, should enter the professional courses of Sibley College. Only an Engineer can succeed in Engineering.

BOOK NOTICE.

NOTES AND EXAMPLES IN MECHANICS, WITH AN APENDIX ON THE GRAPHICAL STATICS OF MECHANISM. By Irving P. Church, C. E., Associate Professor of Civil Engineering in Cornell University. J. Wiley & Sons, 1892; pp-146.

This comparatively small volume is written as a companion volume to the extensive and valuable treatise on Mechanics and Engineering, by the same author. It contains notes and practical examples in illustration of the principles taught in that work, and some additional matter, as well as a brief treatise on Graphical Statics, following Professor Herrmann, the great European authority on that subject. Professor Church has, in his inimitable and effective way, brought this matter into a form which well suits the purpose in view, and has adapted it in all ways to the requirements of that high class of instruction so well exemplified in his own teaching. The volume forms a fitting appendix to his other works and serves to make them still more complete and useful to classes in engineering taking that advanced line of work in which Cornell, and especially its engineering departments, have become so well-known among engineers and applied mathematicians. These departments are now, practically, in a large degree graduate schools to the average technical school of the country, and the labors of the author of this volume have done more than a full share in bringing about this advance, and in thus, through them, contributing greatly to the fame of the University. This little book is an admirable example of such work.

THE CRANK.

Published on the 15th of each month during the College Year, by students of the

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THE CRANK, Box 1501, Ithaca, N. Y.

NOTICE.—In accordance with the requirements of the constitution of *The Crank*, class elections will shortly be held for the purpose of electing two editors from the Junior class, and one from the Sophomore class. The retiring board will elect two Juniors, one Sophomore, and one Freshman, on the basis of contributions received during the year.

COLLEGE ETHICS—ANOTHER VIEW.

Referring to the case mentioned in the February issue, in which the worker complained of the man who, pretending to work with him, shirked and left the willing horse to do all the burden—how ineffably mean the lazy incompetent! A man of honor is not only honest in respect to truth-telling, but just as scrupulously so in his work. The saying, "A Gentleman *can*not, and an Honest Man *will* not, lie," is just as applicable to the pilfering of credit, the gaining of a diploma under false pretenses, or that petty and more common meanness of combined mendacity and larceny, the presentation of the fruits of another man's talent and industry as his own. As honest men and gentlemen, standing up for honor and honesty, acquire more influence among the weaker characters in college life, the moral and intellectual atmosphere will become clearer, and the men of honor and of truth will more and more completely dominate the student body. As rowdyism has, in later years, largely decreased in all the better class of colleges, owing to the gaining strength of the gentleman ("gentle man"), so, as time goes on, may we expect this meanness of the idle and the dishonest to become a matter of tradition, through the predominating influence of the Man of Honor and the Honest Man. And as to work, Ruskin says: "Though you may have known clever men who were indolent, you never knew a GREAT man who was so; and when I hear a young man spoken of as giving promise of great genius, the first question I ask about him is always, DOES HE WORK?"

CRANK SHAFTS.

Two Sibley College inspection tours were made during the vacation, about 30 students taking part in each tour. The electrical engineers visited Schenectady, Boston, Lynn, and Providence. The marine engineers visited the shipyards at Wilmington, Philadelphia, Brooklyn and other places.

Professor W. H. Warren, of the engineering department of the University of Sydney, N. S. W., writes to the Director of Sibley College to say that it is probable that Mr. Barraclough, a Fellow of that university, and of government appointment, will be sent to take his advanced work in Sibley College. The plan requires the approval of the Home Government; but approval is expected as a matter of course.

According to Bertrand, (*Thermodynamique*, p. v), the impossibility of creating energy by finite power was affirmed three centuries ago by Galileo. Nothing, as he stated, could produce a perpetual motion machine; a machine could only transform energy. He taught his students at Padua the aphorism: "No machine ever created power, and none ever can." Sadi Carnot made this principle the basis of a new theory, and thus began the construction of the science of Thermodynamics. (Ibid, p. 37).

Manual training classes have been established in Waterbury, Conn., in connection with the public schools of that city. The work was organized by Mr. J. M. Taylor, (Cornell '89), who designed the work-benches and the course of instruction, beginning the work March 1. The boys in the upper classes in the high school have applied for the privilege of taking the work. It has given the greatest satisfaction. Mr. Taylor is "Supervisor of Drawing" for the city of Waterbury, also, and has established a Normal Class, giving his own time mainly to the instruction of teachers. The Prang "Course in Form Study and Drawing Models" has been the standard for the courses adopted. The report of the board of education and local newspapers give very full and interesting accounts of this work and very complimentary notices of the worker.

George H. Babcock, the distinguished inventor, and builder of the well known "Sectional boiler," is also an inventor in another field and has recently completed, to the stage of experimentation, a new form of gas engine which is thought likely to give exceptionally good economical results. The engine was built by Mr. Juan G. Ribon of Jersey City, and since its completion some months ago has been in store in his works; the inventor not having had time to pursue his investigations of power and efficiency. Mr. Babcock, who is one of the regular Sibley College non-resident lecturers, and much interested in the work done here, has now presented this interesting and valuable machine to the College. It has been sent up from Jersey City, and is in course of erection on a permanent foundation for the purposes of the college laboratory. Its performance will form the subject of the graduating thesis of two members of the class of '92.

The prospectus of the Law School is expected to be distributed at once, and has already been sent out to officers of the University. It is a very neatly made up document and gives an admirable presentation of the opportunities to be found in that department of the University. The frontispiece is a picture of the new building now well underway. The building itself is a very handsome structure. It is crowded upon the library, however, in such a way as to injure the appearance of both buildings, as seen from some points of view. The presence of this school at the University is another of the advantages offered to Cornell students in advanced work in engineering, as well as in law, which latter work may be considered as an essential adjunct to the professional engineering course. Every man of business should know something of law, and especially should the student in engineering be familiar with the law of contracts and related subjects. Here, this class of students have a special claim, as well as opportunities; since the Law School building was erected with funds pledged by the State, as received under the "Land Grant Act" from the general government, for the promotion of the useful arts.

A SUGGESTION TO OUR LEGISLATORS.

"The object of this dedication is to entreat Your Majesty graciously to consider the case of the uneducated English Folk who are now suffering great misfortune in their Trades, Commerce, and Manufactures, as well as in their Social, Moral and Intellectual Condition, through having been neglected and allowed to fall behind other Nations, better cared for, by the men whose duty it is to lead as well as govern the People."—(J. Scott Russell's dedication of his "Systematic Technical Education.")

PERSONALS.

'87.

J. D. Ihlder is with the Eickemeyer–Osterheld Manufacturing Co., at Yonkers, N. Y.

'89.

L. B. Marks is with the Washington Carbon Co., at Washington, Pa.

W. K. Archibald is with the Westinghouse Electric Co., at Pittsburgh, Pa.

A. Kingsbury is a professor at the University of Vermont, at Rutland, Vt.

O. M. Mowatt is with the Yale & Towne Manufacturing Co., at Stamford, Conn.

'90.

G. S. Bliss is with the Bell Telephone Co., at Boston, Mass.

J. J. Ewing is now with the John T. Noyes Co., at Buffalo, N. Y.

F. F. Goodwin is with the Thomson Welding Co., at Lynn, Mass.

H. Cochrane is with the Eliptron Manufacturing Co., at Brooklyn, N. Y.

Percy A. Clisdell is with the Central Thomson–Houston Co., at Cincinnati, O.

F. D. Davis is now with the Yale & Towne Manufacturing Co., at Stamford, Conn.

J. E. Greenawalt has just completed the construction of the

Los Angeles, Cal., Consolidated Electric Railway, and is at present installing an extensive electric mining plant at Prescott, Arizona.

E. C. Fisher, is now the manager of the Chicago office of the Murphy Iron Works, of Detroit, builders of the Murphy Smokeless Furnace. Their "stoker" is an automatic apparatus and occupies the same field as the " Roney Stoker," handled by the Westinghouse interests. It is in use in many places and finds an extensive market. Mr. Fisher has an excellent position for a man so lately out of college.

'91.

J. E. Kress has now charge of the testing department of the Cambria Iron Co., at Johnstown, Pa.

W. H. Meeker is assistant professor of mechanical engineering at the Iowa Agricultural College, Ames, Iowa.

H. G. Van Everen has accepted a position with the Southwark Foundry and Machine Co., at Philadelphia, Pa.

J. T. Gibbs has recently been appointed electrical superintendent of the Milwaukee Street Railroad. When it is fully equipped it will be one of the largest and best equipped roads in the country.

F. C. Perkins is now in London in business with Mr. Wm. J. Hammer, the well-known consulting engineer, formerly with Mr. Edison. Since leaving college he has done considerable traveling in Europe. He is now working up a number of interesting matters, including rapid transit—especially in tunnels—and expects to return to the United States in a few months. Both he and Mr. Hammer are doing much work in preparation for the World's Fair. They are the European representatives of the following electrical interests: Ries Electric Supply Co., Ries & Henderson, Weston Electric Instrument Co., Pilkington & White, J. D. Bishop, H. Ward Leonard, Waddell-Entz Electric Co., The Telemeter Co., and the Ward Arc Lamp Co.

E. L. Etheridge is working at the " World's Columbian Exhibition" at Chicago, in the electrical construction department. Mr. Etheridge has sent to the Director of Sibley College a photograph of the iron work of the great dome of Horticultural Hall, an exceedingly handsome construction and exceptionally large. It will cover, during the exhibition, all the large palms and similar tree exhibits. The work going on at the grounds is enormously extensive and mainly on a very large scale. It is expected that there will be about 150,000 incandescent lamps and above 7,000 arc lamps. demanding about 26,000 horse power to drive the machinery for them. The Babcock and Wilcox Co., of New York, will supply some 20,000 horse-power of boilers, and other builders will add to that immense boiler-plant. It is expected that 30,000,000 or 40,000,000 gallons of water will be demanded each day, for fountains and other purposes, and of this the Worthingtons supply the greater part. The maximum supply at Paris was but 6,000,000 gallons per day, a comparison which will give some idea of the relative magnitude of the machinery exhibits of the two enterprises.

'92.

F. H. McCall is in the Northern Pacific shops, at Cheyenne, Wyoming.

'93.

J. A. Moses is instructor in physics at the Hebrew Technical Institute, New York City.

'94.

W. A. May, who met with an accident in the blacksmith shop last December, has returned to resume his studies in the University.

Chas. A. Cleaver and E. D. McConnell are employed in the department of grading and surveying of the World's Columbian Exposition.

CURRENT EVENTS.

The Senior banquet will be held on May 13.

A course in Russian is being offered by Mr. Babine.

Sage Sophomores banquetted on Wednesday, April 6.

The fourth annual banquet of the Law School was held March 12.

Graduate Treasurer Treman reports the football management out of debt.

The Civil Engineers are planning an inspection tour for the spring term.

Rev. John A. Broadus, of Louisville, Ky., delivers the Baccalaureate sermon, at Commencement.

Richard F. Nelligan, instructor in gymnastics, has accepted an instructorship in gymnastics at Amherst.

The speakers who are to compete for the '86 Memorial Prize, have been appointed. The contest will occur May 20.

Mr. Hudson, Assistant Librarian, has received a call to Leland Stanford, as Assistant Professor of English Literature. He will accept.

Edward A. Ross, Ph. D., of Indiana University, has been appointed to the Associate Professorship of Political Economy and Finance.

Judge Geo B. Turner, '73, of Auburn, has been nominated for Alumni Trustee to succeed President David S. Jordan, whose time shortly expires.

Summer courses in Chemistry, Botany, Mathematics, Languages, Philosophy, and Physics will be given at Cornell during the summer vacation.

Henry Shaler Williams, professor of Mineralogy, will leave Cornell to accept the professorship of Mineralogy at Yale. Professor Williams succeeds Professor Dana.

During the recent vacation, the Glee, Banjo and Mandolin Clubs made an extended western trip, giving ten concerts. The concerts were eminently successful, both from an artistic and financial standpoint.

The faculty has requested Olin Farber, '91, to return the Woodford prize which was awarded to him last summer, his oration having been plagiarized from an oration delivered at Indiana State University.

The Intercollegiate Rowing Association, which consist of Cornell, U. of P., and Columbia, will hold its first regatta on Lake Cayuga, during Commencement week. A 'Varsity race between Cornell and U., of P. and a Freshman race between Cornell, U. of P., and Columbia, will be rowed.

Baseball prospects are unusually bright. Catcher Field of last year's team has returned, and many of the old players are playing again. A number of professional teams will be played this month. Early in May, the team will go East, playing Harvard, Yale, Brown and Fordham. Brown, Vermont, Lehigh and Oberlin will play here during May. Cornell opened the season with two games with the Binghamton professionals, winning both games.

THE CRANK

THE SIBLEY JOURNAL OF ENGINEERING.

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IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

TEST OF A PELTON WATER WHEEL.

In this type of motor a jet of water issues, with high velocity, from a nozzle and enters concave cups or buckets upon the circumference of the wheel; the stream meets the bucket tangent to its inner surface, that loss due to impact may be avoided, and in passing over the curved surface has its direction of flow changed. It is the reaction of the force necessary to cause this change in direction that drives the wheel.

Denoting by Q the volume of water per unit of time, by c the velocity of the jet, by v the velocity of periphery of wheel and by α the change in the direction of flow of the water; we have for the force tending to turn the wheel, (see Church's Mechanics, § 566).

$$P = \frac{Q r}{g}(c - v)(1 - \cos\alpha);$$

and for the work,

$$W = \frac{Q r}{g}(c - v)\,v\,(1 - \cos\alpha).$$

In practice α is made to approach as nearly as possible to 180° in order that the factor $(1 - \cos\alpha)$ may be a maximum. The variable quantities in the right hand member of the equation for work are c and v; c depends upon the head available; and for a given value of c the maximum efficiency, theoretically, is found by putting $\frac{dW}{dv} = 0$, which gives $v = \frac{1}{2} c$.

Messrs. H. G. Hamann and D. J. Jenkins have recently made a series of experiments upon the 12-inch Pelton wheel in the laboratory, of which what follows is a synopsis. With water under a given head, that is c constant, the number of revolutions was varied by changing the load on the Prony brake used to measure the power developed. Q and the revolutions per minute, *i. e.*, v were observed for each load. Then different values of c were taken, ranging from the velocity due a head of 21 feet to that due a head of 54 feet with a ½-inch nozzle, and for velocities due heads varying from 96 to 245 feet with a ¼-inch nozzle; and tests made with v varying as before. The tables show the important points brought out by the experiments.

WATER CONSUMPTION AT MAXIMUM HORSE POWER.

HEAD IN FEET.	HORSE POWER.	TOTAL WATER IN LBS.	LBS. WATER PER H. P. PER HOUR.	NOZZLE.
21.25	0.07	10860	155143	½ in.
31.97	0.14	12960	92571	½ "
43.30	0.21	14760	70286	½ "
54.05	0.29	16380	56490	½ "
99.8	0.13	4340	41097	¼ "
135.1	0.10	6112	32172	¼ "
173.3	0.28	6888	28403	¼ "
207.2	0.37	7620	20700	¼ "
243.5	0.50	8110	16220	¼ "

MOST EFFICIENT SPEED.

Head in feet.		Rev. per minute.	Efficiency.	Ratio of velocity of periphery of wheel to velocity of jet, $v \div c$.
With ½ in. nozzle.	21.25	279	0.58	0.40
	31.97	331	6.66	0.38
	43.30	420	0.66	0.43
	54.05	468	0.64	0.42
With ¼ in. nozzle.	99.8	530	0.46	0.35
	133.3	640	0.47	0.36
	170.9	690	0.47	0.35
	207.2	804	0.47	0.37
	243.5	882	0.50	0.37

It is seen that at most efficient speed, both efficiency and the ratio of *v* to *c* remain constant (with same size of nozzle) while the head varies, which is in perfect accord with the theory. The low efficiency obtained for this wheel is in a large measure due to the roughness of the buckets, as the large efficiencies found by Mr. Coleman were obtained with specially prepared buckets, having a smooth surface and a very thin edge for dividing the jet. The decrease in efficiency with the use of the smaller nozzle is due, probably, to the fact that a greater per cent. of the stream impinges upon the dividing edge, which in the wheel tested was rather blunt.

STRENGTH OF FISH-PLATE JOINTS.

BY WM. BOEHM.

The writer having had occasion to design a plain fish-plate joint for two timbers, subjected to tension only, and to resist a tensile stress of 16,000 pounds, timbers to be of yellow pine, fish-plates of same material, and joint to be of equal strength throughout, computed as follows. Taking the safe tensile, compression, and shearing stress of yellow pine as 1300, 1100 and 130 pounds per square inch, respectively, the following areas are required: For tension 51 square inches, compression 60 square inches, shearing 510 square inches.

A 6 x 12 gives 72 square inches for tension, but as something must be deducted for bolt holes, it is well to try this size, and see what result will be obtained after the size and number of the bolts is determined. Selecting any size bolt, the number can readily be computed, but the size and number must be so adjusted that they will not only give the required strength, but also give the required compression area, which in this case is 60 square inches. Trying an inch bolt, its safe resisting moment is 1473 and the number $n = (\frac{1}{2} \times 3 \times 33000) \div 1473 = 34$ bolts in each timber. These give a compression area of 204 square inches which being more than three times as much as is wanted, we try successively $1\frac{1}{2}$, $1\frac{3}{4}$, and finally find that using a $1\frac{13}{16}$ bolt, whose bending moment is 8769 we get the number $n = (\frac{1}{2} \times 3 \times 33000) \div 8769 = 6$, and the compression area $c = 6 \times 1\frac{13}{16} \times 6 = 65$ square inches, which although a little in excess of that required is near enough for our purpose. Placing the bolts in two rows of three each, we have for the tensile area $6 \times (12 - 2 \times 1\frac{13}{16}) = 50$ square inches, which is approximately the amount required. Since we require a shearing area of 510 square inches and, should shear take place, it would begin about half way between the axis and side of the bolt, we have for the distance between centres $\frac{510}{6 \times 6 \times 2} + \frac{1}{2} \times 1\frac{13}{16} = 8$, and from centre to end $\frac{510}{6 \times 6 \times 2} + \frac{1}{4} \times 1\frac{13}{16} = 7\frac{5}{8}$. This makes the fish-plates 5 feet 2½ inches long, and finishes the computation, but it will be noticed that an enormous bolt is required to meet the conditions--we would hardly expect to see $1\frac{13}{16}$ inch bolts in a 6 x 12 timber, and the knowledge of the strength of such joints was thought to be of sufficient interest to justify an experimental determination as to whether the whole computed number of bolts were actually necessary. To do this a stress of 2600 pounds was selected in order that the joint might be of a convenient size for the testing machine, computation showing that a 2⅝ inch x 1 inch yellow pine timber, fish-plates of same material, bolted together with 8 bolts in each end, $\frac{5}{16}$ diameter and 1½ inch between centers, would be required.

Fourteen of these joints were made and tested with different sizes and numbers of bolts. The results are given in the following table, together with the stresses at which rupture took place :

No. of Bolts in each end.	$\frac{3}{16}''$	$\frac{1}{4}''$	$\frac{5}{16}''$
2	2900	2900	3780
4	5830	5850	7870
6	6950	8250	10300
8	9700	10780	11400
10			11900
12			10350

The bolts bent and the wood sheared in every case except in that of the $\frac{5}{16}$ inch bolts with 8, 10, and 12 in each end, these rupturing transversely, through the bolt holes, without bending the bolts. The experiments show conclusively that the computed size and number were necessary, even to the last sixteenth in diameter and the last bolt, and that a greater number than the computed did not appreciably increase the strength of the joints.

A PHOTOMETRIC STUDY OF ELECTRIC LIGHTS.

BY NELSON H. GENUNG, B.S.

In a complete study of the sources of artificial illumination, quality as well as quantity must be considered. A photometer which will supplant the spectro-photometer as commonly employed with all its long and tiresome processes, one which will enable the observer to explore the visible spectrum both rapidly and accurately, will doubtless prove a useful addition to every photometer room. The "horizontal slit" photometer, recently designed by Dr. Nichols to meet these needs, has greatly facilitated work in this department of physics.

This instrument consists of a direct vision spectroscope, (Figs. I. and II.,) with a horizontal slit. Immediately in front of the slit are two totally reflecting prisms A, A′. The light from the direction C is reflected through the slit and the dispersing prisms P, P′ producing a vertical spectrum viewed by means of the eyepiece E. Similarly the light from the direction D is reflected by the prism A′ into the slit and a spectrum is produced parallel to the spectrum from the direction C. The eyepiece is furnished with a horizontal cross-wire and a diaphragm with a narrow, rectangular opening through which corresponding portions of the two spectra may be simultaneously seen. The eyepiece with the first joint of the telescope is movable about B, the centre of a graduated semi-circle. This whole arrangement is mounted on a car so as to work the same as the ordinary Bunsen photometer.

On increasing the candle power of an incandescent lamp from four to twenty-eight candles, the brightness of the spectrum near the A line increases in the ratio of 1:3.7; while the corresponding increase in the neighborhood of the G line is 1:22. It has previously been noted that at a certain point in the spectrum, approximately $\lambda = 600$, the ratio of the increase in brightness is identical with that of the increase in candle power as indicated by the Bunsen photometer. The vertical line (Fig. 3.) indicates this region.

M. Crova, in a recent communication to the Electrical Congress at Paris, recommended that on a light differing widely in temperature from that of the standard, the arc light in particular, the wave length $\lambda = 582$ be employed. As yet this wave length has not been satisfactorily established. When once permanently settled upon, photometry will be reduced to a comparison of intensities from the two sources of this particular wave length, and thus much of the personal error will be eliminated. But we can plainly see that any personal error, whether due to the Bunsen photometer or to the "horizontal slit" photometer or both, will shift the position of the crossing point. It, therefore, seems necessary that each observer establish definitely the wave length of this region before he can employ this method of photometric study. The term crossing point will here be used as indicating the wave length which in the "horizontal slit" photometer gives the same candle power reading as does the Bunsen photometer.

I. THE INCANDESCENT LAMP.

A set of observations taken by the writer on an incandescent lamp at six different temperatures disclosed curves similar to those in Fig. 3, with a single exception. The crossing point apparently moved toward the longer wave lengths of the spectrum, starting at a low temperature, until about twenty candle power was reached, when it directed itself toward the shorter wave lengths as the temperature of the filament was farther increased. Much longer and more carefully observed sets of observations verified this preliminary study. In figures 4 and 5 the crooked vertical lines connect the crossing points of the curves taken at the several different temperatures of the lamp filament.

A number of sets of observations were next taken by the two observers at temperatures within the range of the incandescent lamp, each observer using the wave length which from the curves seemed to be best suited to his individual case. First one observer would set the two photometers alternately until five observations had been taken on each, then the other would take a similar set and so on. In order to avoid the necessity of changing photometer cars, a small Bunsen photometer was mounted directly over the "horizontal slit" photometer on the same car with it. It is eminently proper to call attention to the fact that the settings of one observer were read and recorded by the other, and that after each reading the photometer car was moved to one side at least fifty centimeters and the observer changed his position before the next setting was made. In all the sets on the arc, as well as on the incandescent lamp, not a single observation was rejected however far out it might be. By thus not allowing the observer to have the slightest knowledge of any of his previous settings, he is unbiased in his judgment as to when the lights from the two sources are of equal intensity.

The following table gives these results in which No. stands for the number of observations in each set ; λ, the wave length employed ; B and H, Bunsen and "horizontal slit" photometer readings in candles. The last two columns for each observer give the mean error of a single observation for each photometer.

N. H. GENUNG, Observer.						F. J. ROGERS, Observer.				
		CANDLE POWER.		Per cent. Mean Error, S'gle Ob.			CANDLE POWER.		Per cent. Mean Error, S'gle Ob.	
No.	λ	B.	H.	B.	H.	λ	B.	H.	B.	H.
10	618	2.37	2.52	3.	4.5	640	2.37	2.76	3.3	2.5
10	"	9.06	8.98	2.7	3.8	"	9.15	9.07	2.5	3.
10	"	16.15	16.87	2.	3.5	"	15.89	16.68	2.1	3.5
10	"	31.06	31.67	1.9	3.6	"	31.57	31.15	2.1	3.
10	"	43.58	43.02	2.8	4.2	"	45.12	44.88	3.2	5.7
25	"	34.05	34.62	2.3	4.1	632	35.25	34.20	2.8	5.3

Results of settings on incandescent lamp.

II. THE ELECTRIC ARC.

In this part of the work the light was taken from the arc at an angle of 35° below the horizontal plane. This was thought to represent the light at its best, at the same time giving a good amount of light from the positive carbon at its hottest point. In order to cancel the fluctuations of the arc, the Bunsen photometer was removed from the "horizontal slit" photometer car and mounted on a separate car at the end of a long projecting arm which would just allow it to pass over the "horizontal slit" photometer. This arrangement enabled the two observers to set the two photometers on the same lights independently and simultaneously. First, however, two Bunsen photometers were used. Twenty-five simultaneous settings on the arc light gave the following results.

	Candle Power.	Mean error of single observation.
Genung	481.7	10 per cent.
Rogers	479.5	11.6 per cent.

A set of twenty-five observations was next taken, using the crossing points that had been employed in the incandescent lamp work, and then a set in which both observers used the crossing point recommended by M. Crova, namely λ = 582. In order not to tire the eyes by too constant application, the observers exchanged places after every five simultaneous readings.

		Candle Power.	Mean Error.
Rogers	Bunsen	508	15 per cent.
Genung	H (λ = 618)	368.5	14.9 per cent.

Reducing each Bunsen reading separately to 500 c. p., in order to cancel the error due to the fluctuations in the lamp, gave 363 c. p. as a mean of the "horizontal slit" readings with a mean error of a single observation amounting to 6 6 percent.

The reverse set gave

		Candle Power.	Mean Error.
Genung	Bunsen	513.6	17.6 per cent.
Rogers	H (λ = 632)	341.2	20.5 per cent.

Reduced to Bunsen 500 c.p., the "horizontal slit" reading is 332 c.p., error 8.4 per cent.

Both observers employing λ = 582 gave the following results:—

		Candle Power.	Mean Error.
Rogers	Bunsen	511	18.6 per cent.
Genung	H.	491	17.3 per cent.

Reduced Bunsen, 500. H. 483. Error, 7.5 per cent.

Reverse set—

		Candle Power.	Mean Error.
Genung	Bunsen	516	14.5 per cent.
Rogers	H.	454	14. per cent.

Reduced Bunsen, 500. H. 441. Error 5.4 per cent.

These sets not giving the desired agreement between the two photometers, the observers took up the work one morning determined to locate the fault. The crossing points for both observers on the arc light, were first determined by means of simultaneous readings and were to their surprise found to be almost identical with those used in the incandescent work and in the first set on the arc lamp.

A set of twenty-five observations was then taken with the following results:

		Candle Power.
Rogers	Bunsen	688
Genung	H (λ = 618)	656

Reduced, H. 500. Bunsen, 526. Error for H, 5.6 per cent.

Reverse set.

		Candle Power.
Genung	Bunsen	594
Rogers	H (λ = 632)	532

Reduced H. 500. Bunsen, 559. Error for H 5.4 per cent.

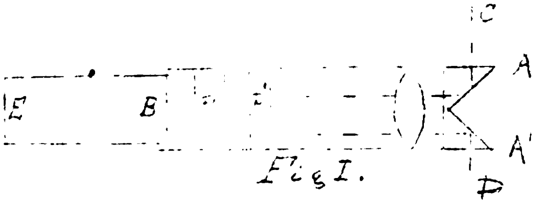


Fig I.

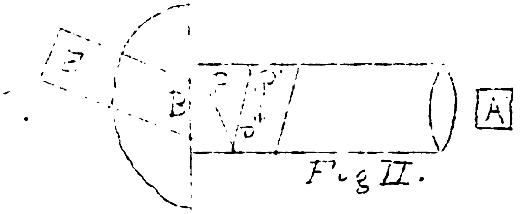


Fig II.

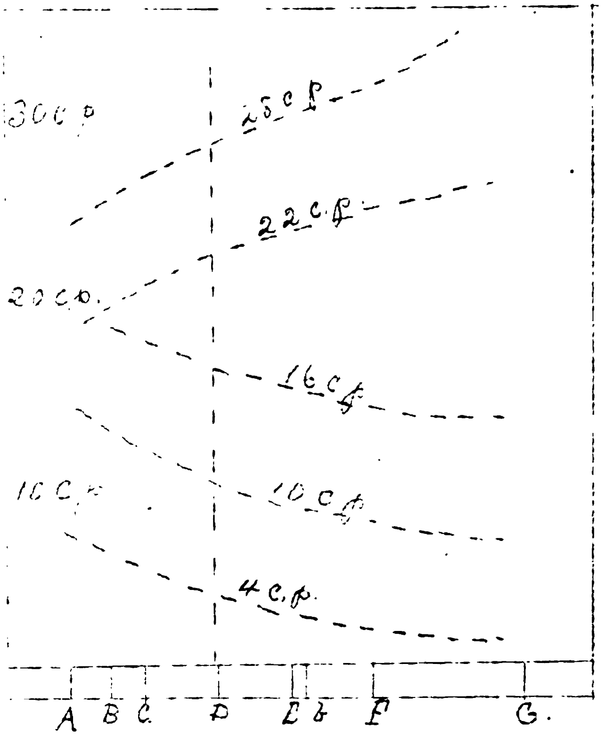
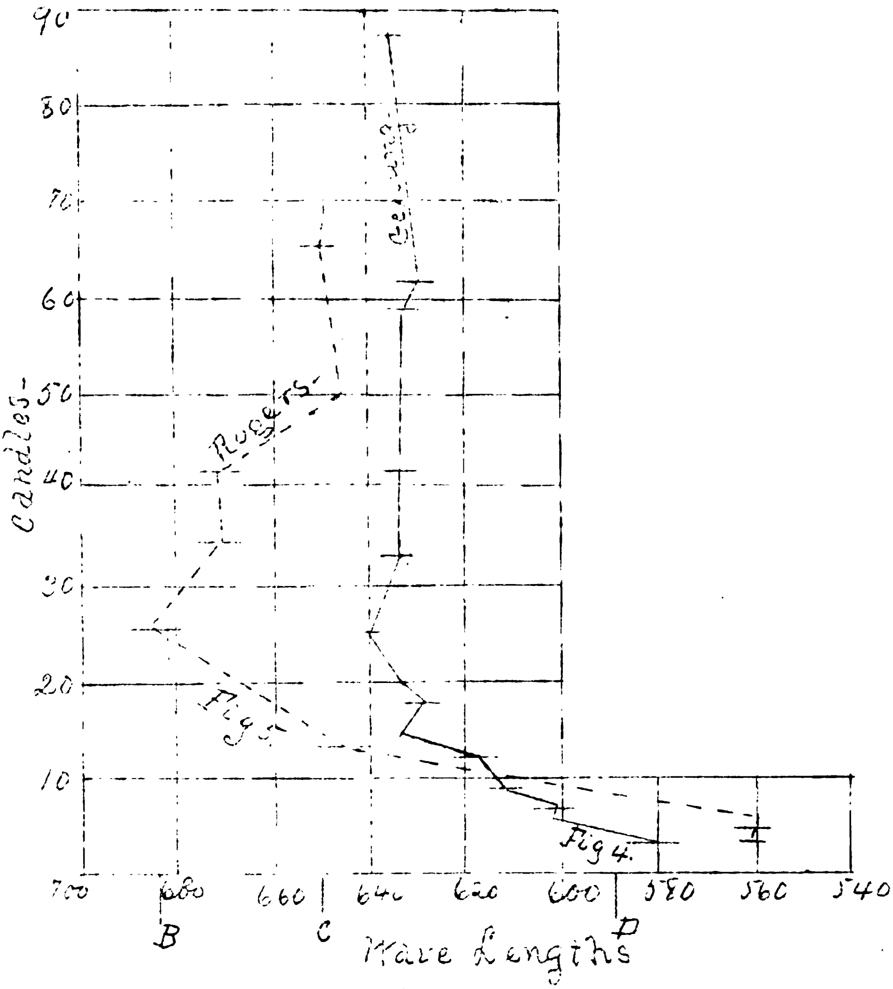


Fig III.


Candles
90
80
70
60
50
40
30
20
10
Rogers
Fig 5
Fig 4.
700
680
660
640
620
600
580
560
540
B
C
D
Wave Lengths

In these last observations an increase in the candle power of the Bunsen readings over the "horizontal slit" readings as the work advanced, was noticed, which would indicate that the crossing points were moving toward the shorter wave lengths. On completing the set the crossing points were redetermined and were both found to be not far from $\lambda = 595$.

What is the solution? One suggestion may be offered. The photometry of fluctuating and intensely bright lights is especially fatiguing to the eyes. They soon became less sensitive to the color seen in the "horizontal slit" photometer, and while this does not effect the comparison made with this photometer, it makes the comparison with the Bunsen photometer a comparison of the lights with this particular color less effective. As the arc is rich in violet light it is placed to an advantage with the Bunsen photometer as the eyes become tired, while the "horizontal slit" photometer gives it its true worth.

EARLY ENGINEERING SCHOOLS.

The *Engineering News* publishes, in recent issues, accounts of the origin of technical education in the United States, and will continue with descriptions of the leading institutions of the day. In its issue of April 21st it gives an interesting account of the opening of the Rensselaer Polytechnic Institute at Troy, N. Y., from which were graduated, in 1840, the first members of the profession in the United States. The methods were somewhat curious: the student was expected to "give an *extemporaneous dissertation*" on the subject in hand in the morning, and to "spend the afternoon in *scholastic amusements*." The italics are from the circular. These afternoon amusements constituted what are now called laboratory exercises; some of them in summer were surveying, collecting, etc., out of doors, and, in winter, making and using various forms of laboratory or other apparatus. These methods were called "*Rensselearian*."

The studies pursued were mainly what are now regarded as high school branches, and were such as are now required for admission. The preparation then demanded was a good knowledge of "reading, writing, arithmetic, and English grammar," subjects not always well known to candidates for entrance into Cornell University, to-day. "*Tuition*, $1.50 for every three weeks, which constitutes a step in the circle" of the sciences there and then taught. Board was "never above $1.50" per week. The costs for a year were estimated (1826) in the "Preparation Branch" at a minimum of $120 a year, including $6 for text-books, $10 for apparatus, washing and lodging $10. The purpose of the founder of the school was to enable men to become "practically scientific." The expenses were estimated, in the college and on all accounts, in 1838, at $94.62, including washing at 18 cents a week, text-books for the year $4, tuition fees $30. Total costs, including those of their field expeditions, $230. Like Sibley College in Cornell University, it was "dependent upon other schools for the literary polish of its own pupils," and its own work was as purely professional as that of the Law School, only teaching "those branches which have a direct application to the business of living," and like Sibley College and Cornell University, but more explicitly, its authorities stated "parents who have not governed their sons at home, and inspired in them the principles of sound morality and the spirit of gentlemen, are respectfully requested *not to send them here.* For the experimental exercises of the school resemble the business of a workshop, in which professors must labor with students, and associate with them as one gentleman associates with another." The degree of Civil Engineer was conferred not earlier than at the age of 17 years.

SIGMA XI ELECTIONS.

At a meeting of the Sigma Xi Society held on Monday, May 2nd, the following were elected from the various courses: From the Faculty:—Frank Angell, L. M. Dennis, W. F. Durand, S. B. Newbury. R. S. Tarr, N. H. Genung, F. J. Rogers. Graduate Students: F. B. Maxwell, Ph.B., Botany and Zoölogy; J. N. LeConte, B.S., Electrical Engineering; E. A. Merrill, A.B., Electrical Engineering; Mary A. Wilcox, Entomology; R. A. Harris, '88, B.H., Mathematics; W. R. Shoemaker, B.S, Mathematics; V. Snider, B.S., Mathematics; E. F. Nichols, B.S., Physics; A. C. Crehore, A.C., Physics and Electricity; Seniors: H. F. Burrage, Agriculture; J. C. L. Fish, and J. M. Michaelson, Civil Engineering; G. C. Farkell, H. G. Hamann, and H. H. Wood, Electrical Engineering; F. P. Ide, D. J. Jenkins, J. Kuhn, and R. T. Mickle, Mechanical Engineering; A. S. Eakle, Science.

OIL TESTS.

In this article are given the results of some commercial tests of oils which were conducted in the Mechanical Laboratory. The tests made were for the coefficient of friction, for viscosity, and for the temperature of chilling, of flashing, and of burning. The friction tests were made on the Thurston Oil Testing Machine, and the viscosity tests in a standard pipette, as used by the Pennsylvania R. R. Co., the time required for 100 c.c. of the sample to run through the orifice being compared with that required for 100 c.c. of lard oil, both at the same temperature. The flash and burning points were determined by heating the oil in an open cup; and the chill point by surrounding a sample of the oil with a freezing mixture, solidifying it and noting the temperature at time of melting. The samples were also tested for acidity with litmus paper.

I. THE FLORENCE OILS.

These are mineral oils refined by the Florence Oil and Refining Co., of Denver, Colorado, and the tests made compare favorably with those made on other mineral oils.

AVERAGE RESULTS.

KIND OF OIL.	Coefficient of Friction.		VISCOSITY TESTS.			Chill Point. Deg. F.	Flashing Point. Deg. F.
	Total pressure, 2000 lbs	Total pressure 1500 lbs.	Time of flow of 100 c.c. in sec.		Relative Viscosity. Water 100.		
			At 100° F	At 75° F.			
Galena Coach. .	0.0085	0.0085	61.8	98	181	42.5	310
Galena Car . . .	0 0055	0.0053	54.1	67.2	157	33.0	290
Galena Engine.	0.0076	0.00765	54.7	67.0	157	31.6	280
Florence Coach.	0.012	0.0127	104.1	268.1	305	48.	284
Florence Engine	0.010	0.009	63.6	97.2	197	38.	230
Florence Car . .	0.0072	0.0068	54.8	82.8	160	32.	230
Lard Oil	. . .	. . . .	90	. . . .	266	. . .	. . .
Water	. . .	. . . .	34.4	. . . .	100	. . .	. . .

II. THE CAROLINA OILS.

These are vegetable oils, being a by-product in the manufacture of turpentine and tar, and were obtained from the Carolina Oil and Creosote Company. Three samples were tested, all of a dark color, having a peculiar, pungent odor, not especially unpleasant. No. 3 is inferior to either No. 1 or No. 2, and is said to be a mixture of them.

SUMMARY OF THE TEST.

Test.	Lard Oil	No. 1.	No. 2.	No. 3.
Viscosity, time of flow of 100 c.c. at 100° F., sec.	$90\frac{3}{16}$	$48\frac{5}{8}$	$55\frac{3}{4}$	$78\frac{1}{2}$
Relative Viscosity—Lard Oil 100.	100	54.0	61.76	86.97
Value as a lubricant from Viscosity—Lard Oil 100	100	185	162	115
Specific gravity compared with water	0.902	0.975	0.986	0.995
Temperature at flash point, Deg. F.	450°	257°	264°	345°
Temp. at burning point, Deg. F.	. . . .	292°	308°	406°
Temp. at chill point, Deg. F.	28°	3°	8°	18°
Test for acid	Trace.	None.	None.	None.
Coefficient of friction, 50 lbs. per sq. in.	0.0106	0.00375	9.005	0.005
" " 100 " "	0.00625	0.00370	0.003125	0.00373
" " Rise in temp., Deg. F. at 50 lbs. per sq. in.	20°	17°	13°	5°
Same at 100 lbs. per sq. in.	15°	20°	25°	10°
Value as a lubricant from coefficient of friction at 50 lbs per sq. in.	100	266	200	200
Same at 100 lbs. " "	100	170	200	167

For the purpose of comparing the given oils with mineral oils, seven of the latter, of different grades, were tested by the same observers on the same apparatus and gave the following results:

	No. of Oil.	Ave. Coefficient of Friction. Pressure 75 lbs. per sq. in.	Viscosity. Flow of 100 c. c. in Sec. Temp. 81° F.
Mineral Oils.	1	0.0068	44.16
	2	0.0075	33.19
	3	0.0081	48.58
	4	0.0087	51.08
	5	0.0050	31.25
	6	0.0060	43.83
	7	0.0050	44.58
	Ave. for Min. Oils.	0.0068	42.38
Carl's Oils.	Av. for Oil No. 1.	0.00372	48.62
	" " " 2.	0.00406	55.75
	" " " 3.	0.00436	78.50

These tests indicated valuable lubricating qualities either as compared with lard or mineral oils. In order to ascertain whether the oils possessed bad qualities which would appear in practical application, they were used for oiling shafting and as a general machinery lubricant. The testimony of their value has been only good, and as they have valuable lubricating properties and also low chilling and high flashing points, they should have a wide application in their use.

CORNELL AS A MODEL.

Mr. William Mather, Commissioner of Great Britain to the United States, reporting on Technical Education in this country, makes the following remarks in his description of the methods of instruction at Cornell University: "Cornell University has led the way in technical education for all the state colleges assisted by 'the Land Grant.' Some of them have already 'lengthened their cords and strengthened their stakes' in this direction, and now furnish excellent scientific training in one or more branches of the mechanic arts, for practical purposes. Perhaps the most salutary effect of the success of Cornell may be seen in the breaking down of the sectarian methods pursued in many colleges founded originally for denominational objects. I have observed preparations being made for imparting instruction in science, especially in chemistry and engineering, of a character eminently practical." Cornell is quoted as "an example among those who are coming out of the old methods of what is termed 'intellectual culture.' The applied sciences are being recognized as forming as sure a basis for character and culture as the dead languages and higher mathematics, for those who have to take part in developing and applying the resources of the country." And speaking of American schools generally, he asserts his belief that "there is nothing better of the kind," and that the "advantages of the training in the best of them is its *practicalness*." He considers that to each one of all our universities and colleges should be "attached departments similar to those at Cornell and Washington Universities, with ample provision for the admission of free students." "Too large a class of young people in America, of both sexes, are seeking pursuits not requiring manual labor. Their education, as given at present, in the high schools and colleges, tends rather to unfit them for the active industries of life in a country where the vast resources of nature are waiting for willing and trained hands to utilize them." Referring to what he thinks is the grandest "Grand Army of the Republic," the 300,000 teachers of the country, large conventions of which body he attended, he remarks:

"If this force should be directed by a change of tactics, so to speak, in the schools, to scientific and technical instruction and to less concentration upon purely literary subjects, there can be no doubt that America will solve the industrial question more rapidly than any other country, and utilize it in the further development of her inexhaustible resources.

THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

The General Meeting of the American Institute of Electrical Engineers will be held at the Grand Pacific Hotel, Chicago, on June 6, 7 and 8. This Institute, organized in New York City in 1884 with Norvin Green as its president, has, from the start, met with the support of the leading electricians of the country, and now stands as their representative organization, similar to the corresponding associations of civil and mechanical engineers. Its object is to promote the arts and sciences connected with the production and utilization of electricity. Technical papers are read at its meetings and are published, with their discussion, in the Transactions which are sent to the members and associates.

At these meetings Cornell has always been well represented, and the coming meeting is no exception, since, of the nineteen papers on the programme, six will be presented by Cornell men. It is also interesting to know that Dr. Edward L. Nichols is one of the vice presidents, and that the President is Prof. W. A. Anthony, formerly a professor at Cornell. The following papers will be read by Cornell men at the general meeting this year:—

"A Dynamo Indicator, or Instantaneous Curve Writing Voltmeter," by Prof. George S. Moler; "The Magnetic Properties of Sheet Iron," by Mr. Milton E. Thompson; "Derivation and Discussion of the general Solution for Current in a Circuit Containing Resistance, Self-induction, and Capacity, and any Impressed Electromotive Force," by Messrs. F. Bedell and A. C. Crehore; "The Reversal of Polarity in Planting Dynamos," also on "Dynamos for Continuous Current Circuits," by Prof. Harris J. Ryan; "The Photography of Alternating Current Curves," by Dr. Edward L. Nichols. Prof. George D. Shepardson, formerly of Cornell, is also expected to present a paper, but his subject has not yet been announced.

The active part which Cornell has always taken in the work of this Institute is of no small value to the University. The papers are read before the leading engineers of the country, and undoubtedly their estimate of the engineering work done here is greatly determined by the work of our representatives. It is not at all improbable that the work of Cornell at the Institute has done much to secure the enviable reputation which Sibley College enjoys throughout the country, and to obtain for her graduates the positions which they hold in the large concerns of this country.

CORNELL AT THE WORLD'S FAIR.

The question of an exhbiit by Cornell University, at the Columbian Exposition, has been put in the hands of a committee of three, of which Professor Fuertes is the Chairman. The committee after having carefully looked over the ground, and considered the various phases of the question, have prepared a report which is now in the hands of the Trustees for action. The difficulty of making an exhibit that would be a fair representation of all the courses, has been kept in mind in the plan presented, and from the extreme divergence of the courses of study and instruction, it has been no easy task to present a plan that would give a fair representation to classical courses as well as those in science and engineering. In a word the plan suggested is as follows: that each course be allotted a certain space, to be filled with photographs illustrating the work of that course, and at the base of the above wall exhibit, being placed show-cases to be filled with books or drawings or other work which may be best suited to represent the department. Above each and every display to be placed a placard which tells the department and the degree to which the course leads, the arrangement being such that at a glance the interested observer will be able to know what courses lead to certain degrees. In this way it is obvious that the technical courses could not be over represented to the exclusion of others having equal rights, and also the exhibit would very largely serve to show the extent and variety of the work carried on at Cornell. To this plan it is easy to offer objections, especially since Sibley College has already in progress of construction machinery for exhibition which will be very creditable to her. This exhibit, however, will doubtless be placed in another portion of the exposition grounds, with the general machinery exhibits. Neither does the plan presented seem to preclude the exhibition, in other portions of the buildings, of any especial displays that particular departments might see fit to make.

ENERGY LOSSES IN ARMATURE CORES.

BY W. E. GOLDSBOROUGH.

In the following article an effort has been made to determine, from data compiled while experimenting upon several electrical generators, the absolute loss resulting directly from the existing circumstances which govern the action of the armature as it rotates in its bearings, and, if possible, to separate this loss into its component parts. The methods used have been those depending directly upon the consideration of curves, since it was considered that this means furnished the most convenient way of easily detecting errors, as well as of making slight corrections or interpolations.

In the case of each machine, it was operated as a motor during the test, without any load whatever, the belt being thrown off before beginning the run. Care was also taken to have all the journals well lubricated, that the friction of the bearings should be as small a factor as possible. Under these conditions, five runs were made, between the maximum and minimum pressures which could be safely applied at the terminals of the field coils; the pressure being kept constant for each run at one of the five points equally spaced between the limits. Then with the field constant, the pressure at the brushes was gradually increased, readings at each advance being taken of the armature current, pressure and speed, until the speed reached the highest safe value, when the run was terminated and a succeeding pressure substituted at the field coil terminals. From these readings, curves of speed and armature pressure were plotted, and since they should be straight lines a correction was made for points falling too far outside the curve. In every case the current value, which was always small, ran up so evenly as to make the plotting of speed and current curves unnecessary. A second set of curves was now plotted for the speed and watts consumed; the field pressure being constant, and the speed increasing.

These curves were now made use of to determine points of constant speed, with varying armature voltage, watts, and field pressure, from which curves were plotted showing the relation between the watts and the armature pressure, which is, of course, proportional to the magnetic density in the armature. The points at which these curves intersect the axes determine the power absorbed in overcoming the friction of the bearings, since, the voltage being zero, the magnetic density in the armature must be zero, as also the losses from hysteresis, Foucault currents and C^2R. Since all of the machines tested were nearly the same size, the friction varied but little in the different machines, being about fifty, one hundred, and one hundred and fifty watts for each of the speeds computed, namely, 500, 1,000, and 1,500 revolutions per minute. Since for a given speed the friction loss is a constant, all consumption of energy above these values must be that diffused in one of the three ways mentioned above, as these embrace the only probable causes that arise to produce such waste. Of these, C^2R only reached a maximum value of four watts in one machine, being much smaller in the others, so that this quantity has been disregarded as being too small to make a difference in the curves. Of the remaining two, since the armatures are all well laminated, the Foucault current loss has also been neglected; to hysteresis being attributed the resulting loss, amounting to many times the friction, as the magnetic density and speed of rotation are increased.

As the final result of the investigation, the magnetic densities existing in the armature cores have been determined from the dimensions, winding, etc., of the same, and following will be found tables giving in a condensed form the loss per cu. cm. per cycle, for a given magnetic density and speed, as existing in these different cores. A comparison has also been made in column H of the values of (a const. × $\beta^{1.6}$,*) and it will be readily seen that the values for the 5-light Weston machine approximate these very closely. This furnishes strong grounds for supposing the the hysteresis of rotation may resemble that of alternation in the marked accordance it has with powers of the magnetization. The results obtained from the Weston and No. 4 Edison, show at a glance what an improvement has been made since the old No. 2 Edison was placed on the market. The most surprising thing, however, is the showing made by the Sprague Motor, the magnetic losses of which are far in excess of those of the other machines, when the normal magnetic densities are used.

$$H = .000543\,\beta^{1.6}.$$

Speed of Machines,—500 Revolutions per Minute.

β	H	Hysteresis loss per cubic cm. per revolution in ergs.			
		5 Light. Weston.	No. 4 Edison. Shunt.	No. 2 Edison. Shunt.	10 H.P. Sprague Motor.
1000	34	37	38	56	27
2000	104	89	80	122	67
2500	150	124	104	161	97
3000	200	166	128	207	133
3500	255	216	155	261	175
4000	315	275	187	325	237
4500	380	340	223	400	325
5000	450	415	270	500	. . .
5500	525	503	343	605	. . .
6000	600	600	466	723	. . .

---

* β = magnetic density per square centimetre.

$H = .000788\ \beta^{1.6}$.

Speed of Machines,—1000 Revolutions per Minute.

β	H	Hysteresis loss per cubic cm. revolution in ergs.			
		5 Light. Weston.	No. 4 Edison. Shunt.	No. 2 Edison. Shunt.	10 H.P. Sprague Motor.
1000	50	86	67	96	48
2000	150	177	141	204	115
2500	215	215	180	267	164
3000	290	283	222	350	235
3500	372	345	266	455	340
4000	457	420	315	583	504
4500	552	512	372	732	720
5000	653	610	450	910	1050
5500	760	720	550	1110	. . .
6000	874	833	713	. . .	. . .

$H = .000862\ \beta^{1.6}$.

Speed of Machines,—1500 Revolutions per Minute.

β	H	Hysteresis loss per cubic cm. per revolution in ergs.			
		5 Light. Weston.	No. 4 Edison. Shunt.	No. 2 Edison. Shunt.	10 H.P. Sprague Motor.
1000	54	95	87	125	70
2000	165	200	180	260	172
2500	239	258	231	350	251
3000	318	327	387	460	370
3500	405	405	348	585	570
4000	500	490	422	718	955
3500	605	580	513	870	. . .
5000	715	688	616	1045	. . .
5500	834	817	735	. . .	. . .
6000	957	964	878	. . .	. . .

Finally, I wish to call attention to a very remarkable set of results obtained from a 110 volt T. and H. compound incandescent dynamo. These results showed such a marked diminution of the magnetic losses that a second set of readings were taken as a check upon the previous work, and resulted in a most satisfactory corroboration. The careful plotting of the curves revealed the fact that after the friction losses, and those resulting from the heating of the armature wire had been subtracted, there was only an inappreciable remainder, of fluctuating amount, to be attributed to hysteresis. This clearly shows the advance made by the Thompson-Houston Company in the quality of their core irons, and demonstrates what careful selection and experiment can do.

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A CHANGE OF ADMINISTRATION.

President Charles Kendall Adams, on the 5th inst., addressed a letter of resignation of his office to the Chairman of the Board of Trustees, to be presented at the next meeting of that Board, now fixed for the 18th of May. The reason for this grave proceeding is stated by the President to be unspecified differences of opinion relating to the administration of the affairs of the University. The change is therefore of the nature of those which result, not infrequently, in the political history of Great Britain, for example, from presumably irreconcilable differences between the legislative body and the cabinet, the rule being that, on such occasions, the latter shall retire to make way for a new set of advisers of the Queen. The reasons are regarded as ample, the consequence a natural one, and the letter written by the President, in this case, seems to be considered by all a dignified and creditable document.

The retiring officer is reported to have said that this decision is intended to be definite and final, and rumors are already afloat regarding the probable successor--somewhat to the discomfort of two or three members of the Faculty. Coming at a time when the foundation of two great universities and the singular demand for presidents among the smaller colleges have combined to threaten the serious disgregation of the Faculty, from which some considerable losses have already occurred and others threaten, and when the usual numerous changes among the instructors have been rendered more numerous and serious by the operation of the same causes, this most momentous event is regarded by many as most inopportune, and the train of events indicated as leading to it as most unfortunate. Should the choice of a suitable successor prove possible; should the professorships left vacant by the resignations of their present incumbents, now called elsewhere by extraordinary salaries or promotions, be filled by equally strong and desirable men, the University will feel comparatively slightly what must, nevertheless, prove one of the most serious crises of her history. A single error in filling important chairs; the error so possible in selecting a president, especially, would prove a permanent and irremediable injury to the institution. Should a president be found large enough and strong enough to appreciate the peculiar requirements, the special opportunities, of Cornell University; should he prove great enough to grasp the idea of its founders, and to see his way clearly to the accomplishment of the task prescribed by Senator Morrill and his coadjutors, of Ezra Cornell and his colleagues, and of the large-minded men who have written the law and directed the course of the University to the present time, and who have made it not only what the people demanded in 1862, but a grander and nobler institution than was even conceived a generation ago, except by a few far-sighted statesmen and earnest benefactors of the people; should he be a man capable of aiding to make it, not only the home of all departments of human thought, but the type of the latest and best, a model upon which every later foundation is more or less formed.; if such a man can be found and can be induced to take up and help carry on this peculiar and promising work, always remembering the purpose of the foundation, never forgetting or neglecting those accessories which are essential to its symmetry as to its perfect success as a "people's college," we may confidently anticipate a prosperity not less extraordinary and not less rapid of increase than has been witnessed during the phenomenal period marked by President Adams' administration. Such a man will choose his men wisely, will promote every right principle and will give to the University, so far as individual effort can accomplish it, symmetrical development, and will make the tasks of every other officer the easier and the more fruitful. The Trustees have a most difficult, though a grand, problem to solve. The whole student body will unquestionably take a supreme interest in their success.

Meantime, all unite in the belief that the retiring President will find reason for pride and congratulation that his seven years of service have been marked by such extraordinary prosperity. The number of students at Cornell has doubled, largely increasing in all directions. In Sibley College departments this gain is about *a thousand per cent.*, a figure, however, due as much to their original abnormal diminutiveness as to subsequent growth. The endowment, thanks to the liberality of friends and to the wisdom of the Trustees in its management, has enormously increased. The scope of the University has broadened, its influence has been greatly strengthened, and its usefulness increased, by the organization of new departments and by the extension of its graduate work, until it has come to be everywhere recognized as one of the foremost universities of the land, as well as, and more than all, perhaps the foremost in its representative character as a modern and highly organized and perfected institution of learning. In this upbuilding of Cornell University, making it a leading institution in magnitude, breadth of field, and character of work, every one who has taken part has good reason for pride and self-gratulation, and the man who has had the place at the visible headship of the University has enjoyed such high privilege as seldom comes to any man in any department of human activity. Here the pen and the robe of office stand far higher than any sword or uniform. Such a privilege is worth a lifetime of endeavor. Every one connected with the University will wish the retiring president a long, a happy, and a fruitful life, for the succession, continuance of all that has been the source of pride and delight to every Cornellian in the past, and, for the University, that further growth into symmetry, strength, and power for good in her prescribed fields, that, in her riper period, all have a right and reason to expect for modern, representative Cornell. Meantime the administration of President CHARLES KENDALL ADAMS will always stand, in the annals of Cornell, famous as that of her first and probably most wonderful period of expansion as a great university.

THOSE "THESIS DRAWINGS."

The regulations of the Faculty prescribe as one of the many conditions of their recommendation of candidates to the Board of Trustees, for graduation, that all such in the regular Sibley College courses shall have concluded their work in the Department of Drawing by the presentation of a "graduating piece," a finished drawing of such excellence as shall be acceptable to the head of that department and such as may be taken as evidence of proficiency in that work. This has always been, especially with the inexpert, a bugbear, and has been seriously objected to. A number of the members of a class graduating a year or two ago went so far as to petition for the rescinding of this requirement. Their request was referred to a committee of Sibley College professors, whose report was unanimously in favor of its retention, as the only specifically required complete and finished drawing in a four years' course, and it was thought that it be better to demand more rather than less. Now comes a letter to an officer of the college from one of the prominent actors in this affair, saying :—

"I remember full well that, during my senior year, I was a very earnest opponent of the 'Thesis Drawing;' maintaining that I never expected to earn an existence at drafting, and hence that time spent at the board was useless. From my present position I conclude that a man does not know what he will do at a future time, and I am very glad that our petition was refused."

The officers of the college and of the University have this experience very frequently. They state that the courses of instruction are planned with reference to the general experience of members of the profession, their own included, with a view to securing the best possible preparation of young men to enter upon their work fitted out with that elementary knowledge and that skill in the use of tools, including the drawing instruments, which the oldest, wisest and most experienced men deem essential; that the course is constantly under supervision, and subject to such changes and improvements as experience and the testimony of the best men in the higher ranks of the profession consider proper, and that it is just in this way that the courses in Sibley College have been brought to a stage which gives them the highest place in the judgment of these men. It is this, largely, which has given Sibley College its standing, and Cornell University its reputation as the ideal American university, and has made both the models for all new institutions having similar aims and fields of work. In harmony with the sentiments thus expressed, it is stated that the course in the Department of Drawing will be next year extended, and will hereafter continue throughout the whole four years, including two periods a week in the sophomore year. The course in descriptive geometry is necessarily reduced to two hours; although considered by many of the distinguished and able members of the profession so important as to demand more time, rather than less. The reduction is unavoidable, in face of a still more important change.

PERSONALS.

'84.

D. E. Lane is with the Eickemeyer and Osterheld Manufacturing Co., at Yonkers, N. Y.

'86.

Wm. Darlington is with the Colorado Smelting and Mining Co., Butte City, Montana. Mr. Darlington recently sent to some of his friends in the University, a piece of ore broken from the 1000 foot level of the "Gagnon" mine, one of the principal mines of the company. The ore will probably yield from 75 to 80 per cent. of copper and also some silver.

'87.

E. C. Boynton is with the Eames Vacuum Brake Co., Watertown, N. Y.

'88.

W. B. S. Whaley, now a consulting engineer at Charleston, S. C., is engaged in making contracts for clients, and in preparing plans of power "plants," cotton mills, cotton gins, electric light and power stations, etc., and gives special attention to financial problems in construction. He still finds time to think occasionally of his old friends and the University, and has just sent to Sibley College, as a reminder, some remarkable specimens of boiler incrustation—sediment of an ordinary earthy character in which are embedded perfect cubical crystals of salts precipitated from the feed-water, through the ignorance or carelessness of those entrusted with its care. The specimens are unique.

'89.

A. L. Register is engaged in the electrical supply business : Philadelphia, Pa.

J. Wilkinson has opened an architect's office in Syracuse, an is meeting with good success, having a large amount of work o hand at present.

'90.

F. G. Schlosser is with the Laclede Gas Light Co., St. Louis Mo.

W. S. Young is with the Deane Steam Pump Co., New Yor City.

H. A. Sawyer is now with the Armstrong Power Co., at Amesbury, Mass.

E. C. Sickles is with the Wenstron Dynamo and Motor Co., Baltimore, Md.

'91.

S. G. Pollard is with the Thomson-Houston Co., Lynn, Mass.

W. E. Lindsay is with the Detroit Electrical Works, Detroit, Mich.

J. F. Booraem is with the Havemeyer and Elder Sugar Refining Co., at Brooklyn, Mass.

C. M. White has recently accepted a position with the American Electric Supply Co., of Buffalo, N. Y.

L. Emerick, coxswain of '89 and '90 crews, and E. E. Fisher have been visiting their friends in town during the past week.

A. F. McKissick is Professor of Electrical Engineering at the Agricultural and Mechanical College of Alabama, at Auburn, Ala.

'92.

C. H. Werner has been elected a junior member of the American Society of Mechanical Engineers.

CURRENT EVENTS.

The Senior class tax is $10.

The Graduate Student's Club held a banquet on April 28th.

The Lacrosse team will play Toronto University and Lafayette.

Robert Collyer delivered a lecture on "Burns" in Barnes Hall, April 25.

An electric railway to run from town to campus, will be built this summer.

'94 has voted to allow only male members of the class to run for the *Cornellian* board.

J. M. Gorman, '92 has been elected general secretary of the C. U. C. A. for the ensuing year.

The Woodford speakers are Breckenbridge, Lewis, Hamilton, McAllister, Shurter, and Studley.

The '92 Memorial Fund will be applied towards building a club house on Percy Athletic Field.

Dr. Willcox, Instructor in Psychology, has accepted the Assistant Professorship of Political Economy.

Two of the nine Commencement speakers will hereafter be selected among the Law School students.

Dr. Thurston has been appointed a member of the World's Fair commission for the sixth judicial district.

Professor Burr has received a call to the Professorship of general European history at Leland Stanford University.

"Christopher Columbus, His Life and His Work," by President Adams, has just been issued by Dodd, Mead & Co.

Professor Fuertes has been given leave of absence for one year. He will spend the time in Europe studying in his field of work.

Sibley College Lecture by W. F. Durfee, on "Some Great Inventions of the Moderns That the Ancients Stole," April 22.

The third semi-annual convention of the New York State Intercollegiate Press Association, will be held in Syracuse, May 19.

Mr. Nelligan will leave Cornell at the end of the present academic year, to accept a position as instructor in the Amherst gymnasium.

Dr. Schurman has declined the Presidency of California State University at a salary of $10,000 a year, preferring to remain at Cornell.

Professor Ross, of the University of Indiana, has been appointed as the new Associate Professor of Political Economy and Finance.

Professor C. F. Osborne, of the Architectural Department, will take editorial charge of the *Architectural Era*, without, however, leaving Cornell.

On May 20th, Mr. George H. Babcock will lecture at Sibley College, on "Steam at 200 Pounds Pressure and over, for High-expansion Engines

Crew matters are in an unsettled state on account of lack of funds. The date of the Intercollegiate Regatta to be held on Lake Cayuga, has not been definitely decided.

The new members of Phi Beta Kappa are as follows: from '92, F. O. Bates, G. M. Davison, C. A. Duniway. E. C. Hills, F. L. Norton, G. H. McKnight, A. W. Kaiser, Miss Lucy Murray, Miss C. H. Swartout. From '93, C. E. Ladd, Miss Margaret Otis.

The Spring Athletic Games were held at Percy Field, May 7. The following records were broken: 440 yards dash, C. G. Shaw time 54⅖ seconds; 120 yards hurdle, W. T. Hastings, time 17⅕ seconds; half mile run, G. W. Rulison, time 5 m. 13¾ seconds; 220 yards dash, F. W. Rane, time 5 m. 13⅕ seconds; running broad jump, A. H. Place, distance 20 feet 6 inches.

Baseball:—The following games have been played at Percy Field: April 17, Cornell 10, Binghamton 3; April 18, Cornell 10, Binghamton 4; April 19, Cornell 3, Elmira 6; April 22, Cornell 8, Syracuse Stars 9; April 23, Cornell 5, Syracuse Stars 8; April 25, Cornell 9, Binghamton 7; April 26, Cornell 5, Binghamton 9; April 29, Cornell 7, Seneca Falls 6; April 30, Cornell 12, Cuban Giants 4; May 12, Cornell 5, Brown 4; May 13, Cornell 6, Brown 6, (eight innings); May 14, Cornell 5, University of Vermont 1. The following games were played on the Eastern trip: May 4 at Cambridge, Cornell 0, Harvard 3; May 5, at New Haven, Cornell 1, Yale 5; May 6, at Providence, Cornell 3, Brown 15: May 7, at New York, Cornell 9, Fordham 4.

THE CRANK

THE SIBLEY JOURNAL OF ENGINEERING.

VOL. VI. JUNE, 1892. No. 9.

IN CORNELL UNIVERSITY

"The leading object shall be, without excluding other scientific and classical studies, and including military tactics, to teach such branches of learning as are related to Agriculture and the Mechanic Arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of Industrial Classes in the several pursuits and professions in life."—[An act donating public lands to the several States and Territories which may provide Colleges for the benefit of Agriculture and the Mechanic Arts, July 6, 1862.]

MODERN PROGRESS IN GENERATING HIGH PRESSURE STEAM.*

BY GEORGE H. BABCOCK.

High pressure steam is merely a comparative term. It depends upon the standpoint. You say in New Hampshire that the White Mountains are high, and in Utah that Salt Lake and the surrounding marshes are low, but really, taking the sea level as a datum, there is very little difference in their altitudes. So in Watt's day 20 pounds per sq. in. was high pressure, and in fact it was difficult to carry even that pressure with safety on the boilers then used. To-day what is considered high pressure on board a steamboat, on a locomotive, or an Ohio river steamboat, is looked upon as low. In considering the subject before us we must first define for ourselves the term, "high pressure steam." The standard is continually rising, and in view of this tendency, and the present practice, we shall be justified in classing anything over 150 pounds as "high pressure," though 250 pounds and even 500 pounds are talked of and attained in some instances.

There is nothing new or modern in the idea of the use of steam at high pressures, particularly if we accept the definition in vogue at the time, indeed, there seems to have been a tendency from the very first to employ high pressures. As early as 1697, Savery made an engine which forced water against 80 feet head —say 40 pounds pressure—and stated that he could force it against 1,000 feet if he could get vessels strong enough to stand the pressure. In 1766, Blakely made the first sectional boiler in order that he might carry higher pressures, and though we find no record of what that pressure was, the fact that the experiments were terminated by an accidental bursting of one of the steam vessels through the force of the steam, at a pressure much below what had been proposed, shows that the intention was to use very high pressure.

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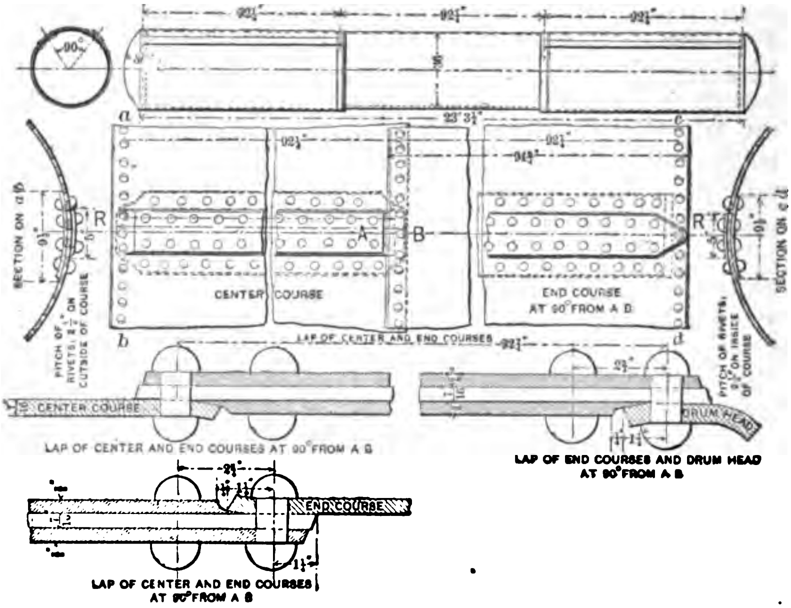
* Lecture delivered at Sibley College, Cornell University, May 20, 1892.


90°
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a
b
c
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A
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R
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PITCH OF RIVETS 2½" ON OUTSIDE OF COURSE
PITCH OF RIVETS 2½" ON INSIDE OF COURSE
CENTER COURSE
END COURSE AT 90° FROM A B
LAP OF CENTER AND END COURSES
CENTER COURSE
DRUM HEAD
LAP OF CENTER AND END COURSES AT 90° FROM A B
LAP OF END COURSES AND DRUM HEAD AT 90° FROM A B
END COURSE
LAP OF CENTER AND END COURSES AT 90° FROM A B

Fig. 1.

Oliver Evans may be fairly credited with the earliest use of what may be termed high tension steam. In 1787, he obtained a patent from the state of Maryland for a high pressure engine, but it was not until 1800 or 1801 that he secured funds to construct one, with which he drove a plaster mill carrying a pressure of 100 lbs. In 1840, John Cox Stevens built a pipe boiler (which is still in existence) which he put on a boat, and worked at a pressure of 50 pounds. In 1815, Trevitheck in Wales, built a locomotive which used as high as 145 pounds steam on occasions, and in 1815, he had a pumping engine running at 100 pounds, though he did not use or recommend, as a rule, more than 25 or 30 pounds, which was then called "high pressure."

Jacob Perkins, however, was the great apostle of high pressure, for he and his sons have been working at and advocating extreme pressures for the last seventy years. In 1822, he designed a boiler into which he injected water, getting steam at enormous pressures, in fact he is said to have heated water red-hot, generating a pressure which he estimated at 56,000 pounds to the square inch. He built an engine and boiler for using steam at 700 pounds, and succeeded in supplying steam at that tension, but the temperature was too high for any lubrication he could command in the cylinder. Traces of experiments by the Perkinses are scattered all along from that time until now. In 1872, they built a tug, the "Filga," which used 250 to 260 pounds, and in 1880, the "Anthracite," built by them, crossed the Atlantic and created some stir in engineering circles. Her boiler was a modified form of that of 1822, with the injection feature abandoned, and the pressure carried was from 300 to 400 pounds per square inch.

In 1850–60, J. W. Rowan built a number of ships with compound expansion engines and high pressure boilers, using steam at 100 pounds and above, but the ships were not a commercial success.

Notwithstanding these instances of the use of unusually high pressures for the times, low pressures remained the general practice, particularly in marine service, until a quite recent period. The usual pressure used at the commencement of ocean steam navigation was but 2 to 4 pounds above atmosphere. Thirty years later the Cunard Line employed but 15, while a few other vessels went as high as 30, and some of the North River steamboats up to 50 pounds. At this time, 1867, a list of English steamers was published, in which the pressures used in 45 vessels, including several tug boats, were given, showing an average for the whole of but 27.3 pounds. The highest was 60 pounds, the lowest 14.

The beginning of what may be termed the era of high pressure in steamships was ushered in about a dozen years ago by the advent of the "Arizona" with 86 lbs., soon followed by the "City of Rome," the "Normandie" and "Furnicia" each carrying 90 lbs. Then came the "Alaska" and "Oregon," the "Umbria" and "Etruria," the "Ems," etc., with 100 to 110 lbs., and now we have the "City of New York," the "City of Paris," the "Normannia," "Prince Bismarck," the "Teutonic" and "Majestic," all carrying 160 to 180 lbs.

Locomotives have been ahead of other forms of engines from the first, in this matter of high pressure. As said before, Trevitheck in 1805 ran a locomotive with 145 lbs. steam, as an experiment. At the famous Rainhill competition in 1829, the pressures were limited by stipulation to 60 lbs., which at that time was thought to be pretty "high." The earlier locomotives of this country, however, used generally about 100 lbs., gradually raised to 125 lbs., which was the average some years ago. Now the later locomotives carry 180 lbs., and use compound cylinders.

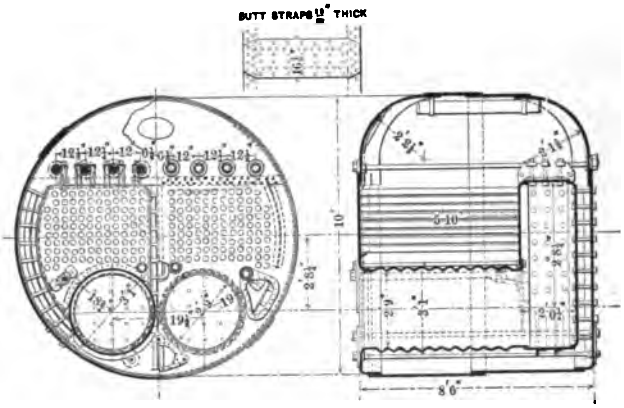


Fig. 2.

In stationary engines, pressures higher than 60 to 80 lbs. have been very rare, though Galloway said that it was no uncommon thing in his day (1830) to find boilers in this country carrying 200 and 300 lbs. It must be that then as now, things were sometimes seen in inverted perspective, distance lending magnitude to the view.

Mr. Wm. Fairburn is quoted as saying that "danger in the use of high pressure does not consist in the intensity of the pressure to which the steam is raised, but in the character and construction of the vessel that contains the dangerous element."

James Watt limited his pressures to about 2 pounds above the atmosphere, mainly because the character of the boilers at his disposal was not adapted to more. We talk of large boilers now, but the largest of this age are pigmies compared with the one

Watt put at work at Dolcoath mine. It was 24 feet in diameter and 24 feet high, and its furnaces held thirty tons of coal at one time. It was the cylindrical boilers of Oliver Evans and Trevitheck which permitted them to increase the pressure. Probably one reason why marine engines were so far behind locomotives and stationary engines in using high pressure, was on account of the large boilers then and still used, as a rule, for ocean-going steamers. In 1867 *Engineering* said that the limit of pressure safe to carry on large shell marine boilers was reached at 50 lbs. The unwisdom of such predictions is apparent now, upon seeing 16 ft. boilers running at 180 lbs., with apparent safety. I say "apparent" because, should one of them once explode, the results would be, doubtless, as unprecedented as are the pressures. In 1867 a boiler of the Greek steamer "Bouboulina," an old blockade runner revamped, exploded on the Mersey, literally tearing the ship in two, blowing the bow in one direction, the stern in another, and the boilers at right angles thereto. It was said to have had but four pounds of steam on at the time. How much worse would be the result of the explosion of one of our modern marine boilers, carrying 180 lbs. steam.

But the fact that we do not have any more explosions now in proportion to the number of boilers used, than occurred when low pressures were carried, shows that progress has been made in "the character and construction of the vessels containing the dangerous element," to quote again Sir Wm. Fairburn's words. It is not merely that engineers and the public have been educated by usage to a point where they can witness without alarm, what would have caused them to flee for their lives but a few years ago. There has been real progress in boiler making, and in the materials used therefor, so that these higher pressures are really as safe as 50 lbs. may have been in the boilers of 1867. Improved materials have much to do with it—better workmanship more. In those days it was quite impossible to get sheets of homogeneous metal, of a quality demanded by modern boiler work, but had they been obtainable, neither the tools nor workman could have been found to make them into the modern boiler. Punching machines, drifting pins and riveting hammers were about the only tools then required for a successful boiler works, and hydraulic or machine riveting was in its infancy. For a long time machine work was decried as inferior to work done by hand, and even now "fossils" may be found who will still echo that cry, notwithstanding it is a well settled fact that only machine riveting, and that of the best, is adapted to carrying the high pressures demanded in these days.

This cry that the days of the fathers were better than these, and their ways more to be desired than those of their degenerate sons, has been heard for more than three thousand years, but nevertheless the world is continually improving, though it is true that in mechanics, as well as in organic life, there are frequent reversions to the original type, and every age witnesses so-called "improvements" which are in reality mere steps backward.

The character of the riveted joints has much to do with the ability to carry high-pressure steam in the boilers of to-day, for though in the best types of boilers much of the work is without rivets, yet even they have steam and water reservoirs which have to be put together in that manner. Welding the joints of boilers has not yet been brought to the point where it can be safely depended upon. It is true that welded furnaces are in common use in the high-pressure marine boilers of the principal ocean lines, but the joints in these are exposed only to crushing strains. So far, welded drums for internal pressure have not proved satisfactory. What may yet be accomplished by electrical welding, or possibly spiral welding, remains to be seen.

A riveted seam for high-pressure requires great care. The edges of the plates should be bent to the proper curvature before being rolled into form, else the seam will be flat and the contact imperfect. The best method of doing this is by a hydraulic press and dies, through which the sheet is passed until the whole length is treated. If the edges are heated for this process, so much the better, as the heating not only anneals the metal, but loosens any scale there may be on the surface, which would tend to prevent close contact. The straps—for the seam must not be simply lapped—must be treated in the same way. When these are fitted so as to lay as closely to the shell as possible without bolts, then enough holes are to be drilled, somewhat smaller than the rivets, to admit of sufficient bolts being put in place to bolt the whole together snugly, after which the rivet holes are drilled through both thicknesses at one operation. As the work progresses turned bolts fitting the rivet holes are driven in every three or four holes, and drawn up snugly. The circular seams, if there are such, must be first drilled, starting in the centre of sheet and working towards edges, so that the sheets may be snugly held together before the longitudinal seams are drilled, and the bolts provisionally placed in these longitudinal seams must be slackened to allow the sheets to adjust themselves as the circular seams are drawn up. As the rivet holes are drilled, if the bolts do not readily draw the sheets into close contact, means should be used to set the plates up iron and iron. After all the holes are drilled in this manner, all the bolts should be removed, the plates taken apart, and the holes countersunk on both sides to remove any fins left by the drill, after which they must be cleaned thoroughly from all chips or borings. The parts are then again assembled, and the rivets driven from centre of seams outward, all riveting being done by machine, except such as the machine will not reach. Flanged heads must be made a driving fit, otherwise they cannot be drawn up tight. The quality and kind of rivets need also to be carefully looked to. When driven by machine and finished hot, steel rivets are the best, but if to be driven by hand iron rivets only should be employed. The reason for this is that with all steel there is a critical temperature, at which if worked it becomes quite brittle. This is known as a "black heat," that is, just below red. Probably it varies with different steels, but that it exists is without question. In riveting by hand it is customary to hammer the rivets until cold, and it is not an uncommon thing to find the heads of hand-driven steel rivets dropping off from this cause. Iron does not seem to possess that quality.

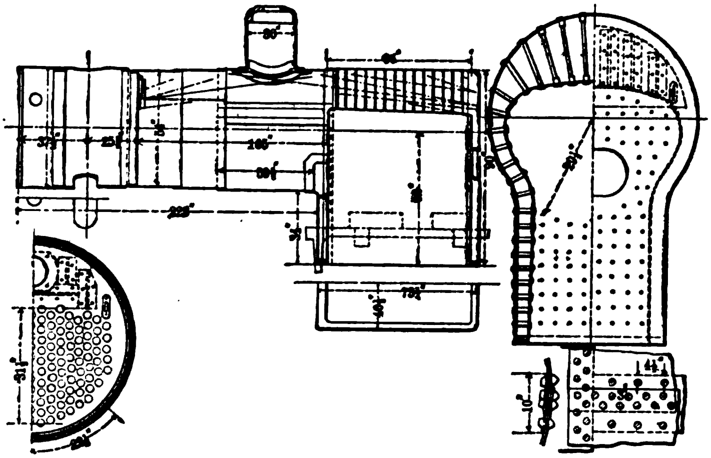


Fig. 3.

Figure 1 shows the character of seam, and the arrangement of rivets best adapted for high pressures, say 200 to 300 pounds, being both strong and tight. It is a double strap, the inner one wider than the outer, and four rows of rivets, as shown.

Figure 2 shows a marine boiler for U. S. Cruiser No. 2, for 160 pounds pressure. It is of the approved marine type, and with single-strap, butt-riveted joints, which will answer for that pressure. It will be noticed that flat surfaces have been avoided as much as possible.

In the locomotive for 180 pounds pressure, shown in Fig. 3, the joints are also butted with straps, and the flat surfaces stayed every 4 to 4½ inches. This is the latest and most approved construction of the Baldwin Locomotive Works.

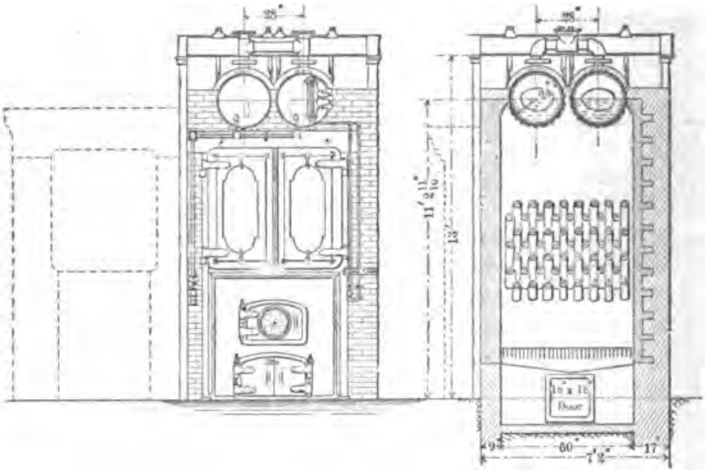
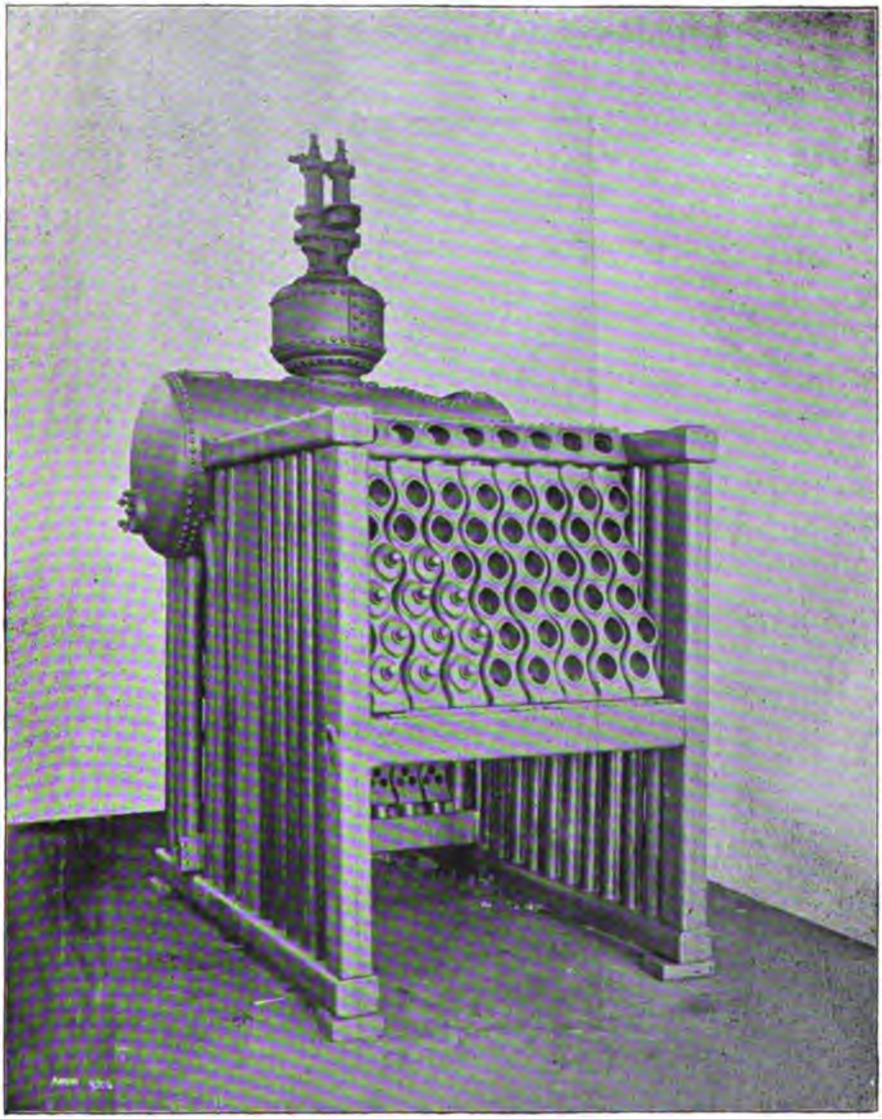


Fig. 4.

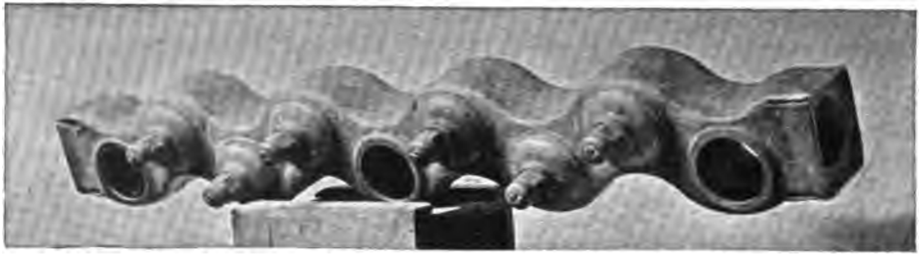
These boilers, Figs 2 and 3, illustrate very fully the difficulties which beset the engineer when designing boilers of the shell variety for such high pressures, and point to the desirability of resorting to some construction in which large shells and flat surfaces may be dispensed with. Such a construction is found in the water-tube boiler, but it is by no means easy to design a water-tube boiler having all the requisites for high pressure, particularly for marine use, while for locomotive purposes they are almost out of the question. For stationary use a large number of water-tube boilers are working at 160 pounds and above. Figs. 4 and 5 show one for 500 pounds at the works of the Consolidated Safety Valve Co., Bridgeport, Conn.

For marine purposes little has yet been done in water tube boilers, though very much has been attempted. The failure of the boilers on the "Montana" and "Propontis" was so complete, and, being supplemented by many other unsuccessful attempts



BOILER FOR STEAM YACHT "REVERIE."

(*Fig. 7.*)



HYDRAULIC FORGED STEEL HEADER.

(*Fig. 8.*)

to introduce water-tube boilers on ship-board, it has tended to make ship owners very conservative in that regard, though it is almost or quite universally admitted that the coming marine boiler for high pressures must be of the water-tube type. The large number of Belleville boilers placed on French steamers, notwithstanding the serious difficulties met with in their use, and the attempt by the U. S. Government to apply a water-tube boiler on one of its cruisers, as also many attempts at water-tube boilers for yachts, more or less successful—generally less—emphasizes this demand for a practicable water-tube marine boiler. The conditions necessary are :

1st. It must be all wrought iron or steel, not only because of the advantages of such construction, but because no other would be passed by Government inspectors.

2d. It must be without stayed surfaces, and yet should have a furnace surrounded by water, as purely brick-set furnaces are scarcely admissible on ship-board.

3d. It must be convenient of access for cleaning outside and in, and for repairs, with the least stoppage in case of accident.

4th. It must be a "free steamer," and yet economical in the use of coal—two points of excellence not easily reconcilable.

5th. It must have sufficient water and steam capacity to prevent too rapid fluctuations in pressure when handled by ordinarily skillful firemen.

6th. It must be economical in room, and to this end the grate should occupy, as nearly as possible, the whole floor space.

7th. It must have a free circulation of water, uninfluenced by the motion of the ship, and not be liable to foam or to rapid changes of water line.

8th. It must be mechanical in construction, and not liable to get out of order.

9th. It must be reasonably safe from destructive explosion—that is its construction must be such that the rupture of any part will not endanger the safety of the ship.

10th. It must be capable of carrying pressure up to 250 lbs. without being excessively heavy.

11th. It must be capable of furnishing dry steam under all circumstances.

It need scarcely be said that a boiler fulfilling all these conditions beyond criticism has not yet been made, and it may devolve on one of the young gentlemen present to furnish the remaining links in perfecting the high-pressure boiler. The nearest approach to it which I am able to show you to-day is in some of the boilers I am now about to exhibit.

Figs. 5 and 6 are two views of the boiler of the steam yacht "Reverie" as it was partially erected in the shop before delivery. The sinuous headers, as well as the square tubes, are all wrought steel, made by hydraulic forging, and all parts are connected by expanded wrought-iron nipples. The water tubes are set in groups of three, so as to be accessible from the hand holes. The furnace sides are flanked by vertical tubes, fire-bricks fitted to the tubes being placed between them, outside, their whole length. When in the yacht these sides, and in fact the whole boiler, is covered with two thicknesses of sheet iron enclosing magnesia for a non-conductor. This boiler has been in use two seasons, steams freely and economically, carrying 225 lbs. in regular work, is perfectly tight, and so far is quite satisfactory. A similar boiler has been in use on a tug boat on the Seine, owned by *La Compagnie de Navigacion du Havre à Paris et Lyon*, for nearly three years, with satisfaction.

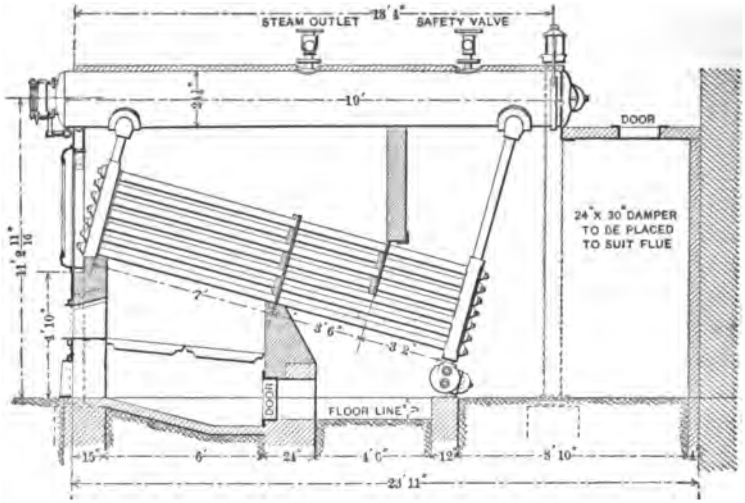


Fig. 5.

A similar boiler has been built for larger powers, having 2,025 square feet of heating surface and 45½ square feet of grate. In this boiler large tubes are placed next the fire, and smaller tubes above, for a better extraction of the heat, and to permit a combustion chamber between. It will be noticed that the two banks incline in opposite directions. This is important, neutralizing the effect upon the water circulation of any pitching of the ship. This drawing will bear close study, as embodying the best results of many years study and experience in the adaptation of the water tube boiler to high pressure marine purposes.

The details of this boiler are worthy also of your attention, the hydraulic forging particularly, being something greatly in advance of anything heretofore attempted in that line. It is shown in perspective in Fig. 8. This is made out of a sheet of steel, passing through several operations, and three principal heats. At the first heat it is bent in dies into a square tube with rounded corners, and the lap on one side. It is then brought to a welding heat, slipped into a mandril and passed through the welding rollers, from which the mandril is then removed, and a sectional mandril substituted, when it is slid into dies in a powerful hydraulic press which corrugates it into the form shown. It is then reheated, after small holes have been drilled where the tube holes are to be, and placed in a press which, working through these holes, embosses the spaces for hand holes. The ends are then welded in and the machining done, which consists of drilling the tube and hand holes, and facing the bosses for hand-hole covers.

There is also on the platform a specially fine hydraulic forging for the cross box shown in Fig. 3, for connecting the tubes to the steam and water drum. This is forged from a single sheet at one operation, for those of ordinary projection, but for those having more projection from the cylinder line, sometimes two or three operations are required.

FRICTION OF JOURNALS.

BY R. T. MICKLE AND J. KUHN.

Previous to the year 1877, comparatively little had been done as regards the friction of journals, but from then on there seemed to be an increased interest taken, which led to some work which gave useful results. The principal workers in this field were Professor Kimball, Professor Thurston, B. Tower, A. S. Wellington, C. J. H. Woodbury and J. E. Denton.

From the results of all these there are certain things apparent. For instance, suppose the velocity of a journal to be constant, also its temperature; the coefficient of friction does not remain constant with change of load, as Morin gives it, but decreases; in fact, in place of the coefficient remaining constant, the friction itself appears to remain nearly so. Next, suppose the load not to vary, then with a certain temperature, the coefficient decreases as the journal moves faster, up to somewhere between 100 and 150 feet per minute, then it increases again. This point of minimum coefficient depends upon the temperature.

It is known that the coefficient is not the same when one metal rubs, in one case on a second, and then against a third. Say brass on steel and then on cast iron. With the object of determining what these coefficients are, and how they varied, a machine was built as described in the following:

On a horizontal shaft were mounted three collars, one of cast iron, one of wrought iron, and one of steel. On these collars blocks of bronze to be tested were placed, and the load applied to them by means of a screw and lever. The test pieces were fastened to a scale beam by two bolts, through one of which a hole was drilled to afford a place for a thermometer, by which the temperature of the bearing was obtained. The scale beam was in the form of an inverted truss, and had steel scales, divided to hundredths of an inch, fastened to it. By means of these scales the lever-arms of a poise of twenty pounds weight was measured, and from this the moment about the center of the shaft due to friction was obtained. Dividing this moment by the radius of the collar gave the friction in pounds, which quotient divided by the actual load on the bearing, gave the coefficient. Lard oil was used for lubrication throughout, and the journal was kept flooded.

Seven samples were tested on each collar. Their composition and coefficients for pressures of 250 pounds per square inch, and a speed near 500 feet per minute, are given in the following tables:

Sample A.—	Copper, ...	79.70	per cent.
	Tin, ...	10.00	"
	Lead, ...	9.50	"
	Phosphorus, ...	0.80	"
		100.00	
Sample B.—	Copper, ...	74.90	per cent.
	Tin, ...	9.40	"
	Lead, ...	9.45	"
	Zinc, ...	5.45	"
	Phosphorus, ...	0.80	"
		100.00	
Sample C.—	Copper, ...	78.45	per cent.
	Tin, ...	9.80	"
	Lead, ...	11.75	"
		100.00	

Sample D.—Copper, ...	74.20	per cent.	
Tin, ...	9.30	"	
Lead, ...	11.15	"	
Zinc, ...	5.35	"	
	100.0		
Sample E.—Copper, ...	87.5	per cent.	7 to 1.
Tin, ...	12.5	"	
Sample H.—Copper, ...	85.71	per cent.	6 to 1.
Tin, ...	14.29	"	
Sample I.—Copper, ...	83.34	per cent.	5 to 1.
Tin, ...	16.66	"	

BEARINGS ON WROUGHT IRON COLLAR.

Pressure, 250 lbs. per sq. in.

Sample.	Velocity in feet per minute.	Temp. at which coef. was taken.	Coefficient.	Friction per sq. in. of bearing.
A	500	105.4	.0025	.6355
B	475	117.8	.0040	1.0004
C	478	110.5	.0055	1.3817
D	458	113.	.0056	1.4111
E	473	113.1	.0055	1.3692
H	468	111.1	.0043	1.0829
I	500	115.	.0043	1.0765

BEARINGS ON STEEL COLLAR.—*Pres. 250 lbs. per sq. in.*

Sample.	Velocity in feet per minute.	Temp. at which coef. was taken.	Coefficient.	Friction per sq. in. of bearing.
A	500	107.9	.0042	1.0678
B	475	125.8	.0061	1.5199
C	478	113.5	.0040	.9977
D	478	117.8	.0049	1 2251
E	473	113.1	.0052	1.3063
H	468	112.7	.0045	1.1268
I	500	117.3	.0038	.9565

BEARINGS ON CAST IRON COLLAR.—*Pres. 250 lbs. per sq. in.*

Sample.	Velocity in feet per minute.	Temp. at which coef. was taken.	Coefficient.	Friction per sq. in. of bearing.
A	500	104.8	.0040	1.0049
B	475	121.0	.0069	1.4741
C	478	122.4	.0091	2.2969
D	478	127.8	.0070	1.7623
E	473	116.1	.0074	1.8409
H	468	117.6	.0066	1.6614
I	500	120.1	.0043	1.0829

Besides the above, a run was made on sample A at various speeds and pressures. Regarding the results it is sufficient to say that they corroborated the statement made at the beginning of this article, *i. e.*, with an increase of velocity the coefficient increases (the lowest speed was over 200 feet per minute); with an increase in pressure the coefficient decreases, and with an increase in temperature it decreases. From this it would seem that the proper way to run a journal would be, at a surface speed of from 100 to 150 feet per minute, to make the pressure on a given area as high as possible without introducing the danger of cutting, and as a consequence of the last—also as shown by the results of the experiments directly—to run the journal at about 100° temperature. It must be noted that as these results were obtained with lard oil, they apply only to that.

OIL TESTS AT HIGH SPEED.

BY I. J. MACOMBER, M.E.

These tests were taken up for the purpose of determining the effect upon lubricants of the high journal speeds which are usually employed in connection with electric generators and motors; also to determine the oils which may be put to use for this purpose.

The apparatus used in these experiments was the Thnrston Oil Testing Machine, which is too well known to need description here. The oil so far used was such as is to be obtained in sufficient quantities in the mechanical laboratory. Before beginning the tests the apparatus was put in good order and calibrated. An electric motor was used to run the spindle of the testing machine, and by this means any desired speed could be obtained. The work that has now been done is practically but the beginning of what should be accomplished in this direction.

The results so far obtained are shown by the curves in the accompanying plates. The speed at which the testing machine was run in most cases was 3,000 rev. per. min., or a journal speed of a trifle over 1,000 ft. per. min. The quantity of oil used was just sufficient to produce the conditions of a flooded bearing, or, as nearly as possible, the least quantity of oil was fed to the journal as would produce the least coefficient of friction at the given speed or pressure.

In plate No. I, we have the curves for several oils plotted for

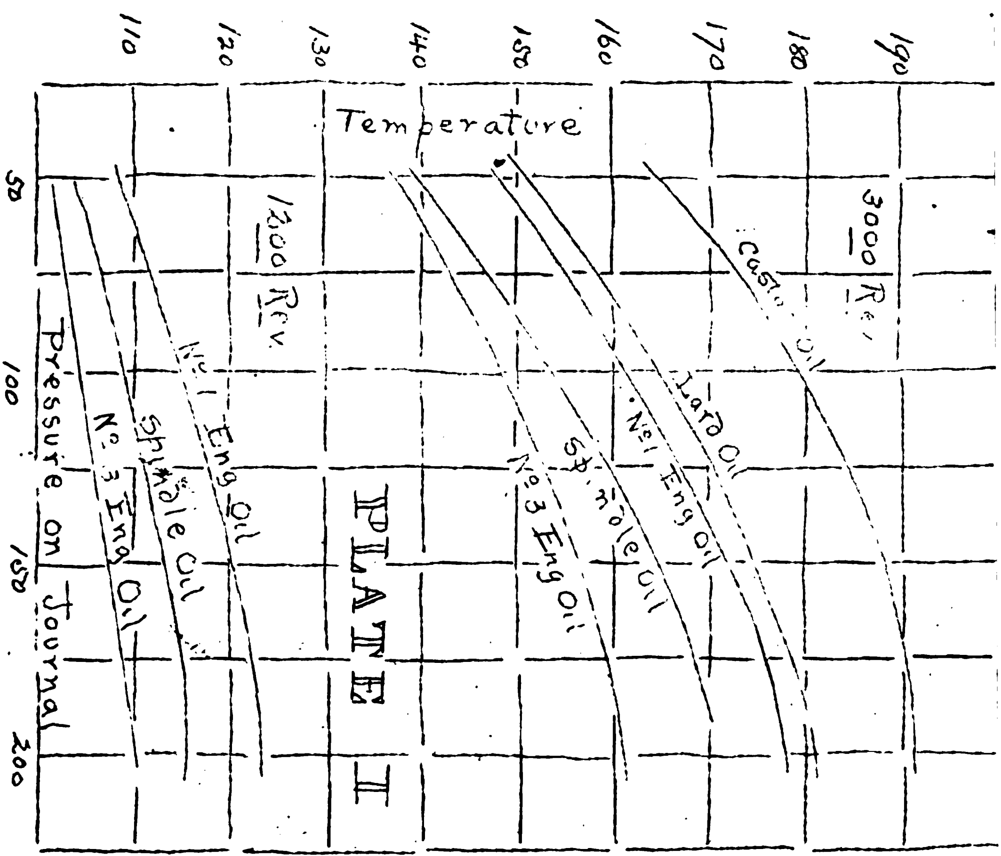


PLATE II

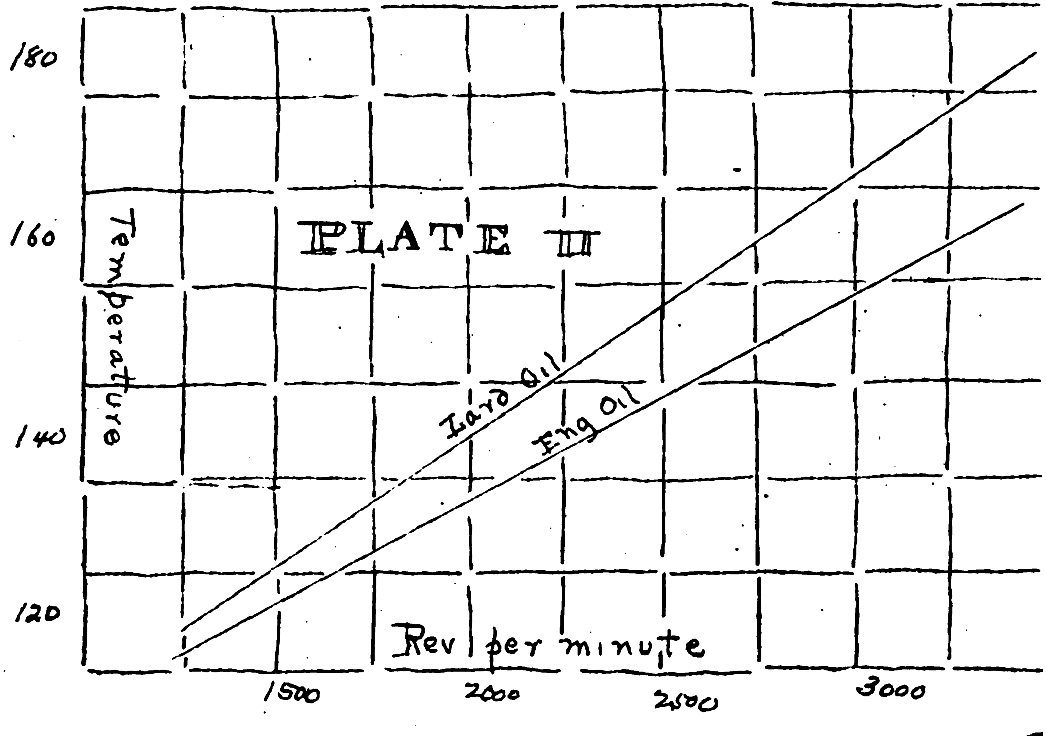


PLATE III

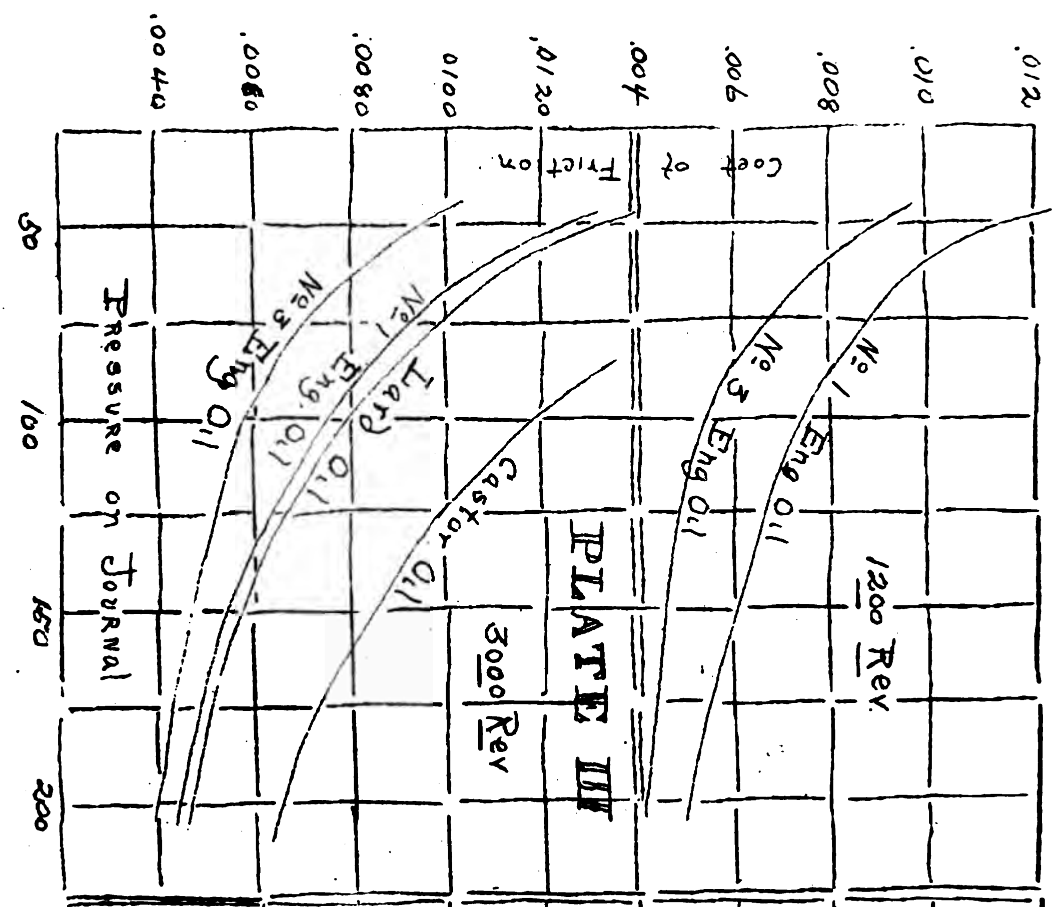


PLATE III

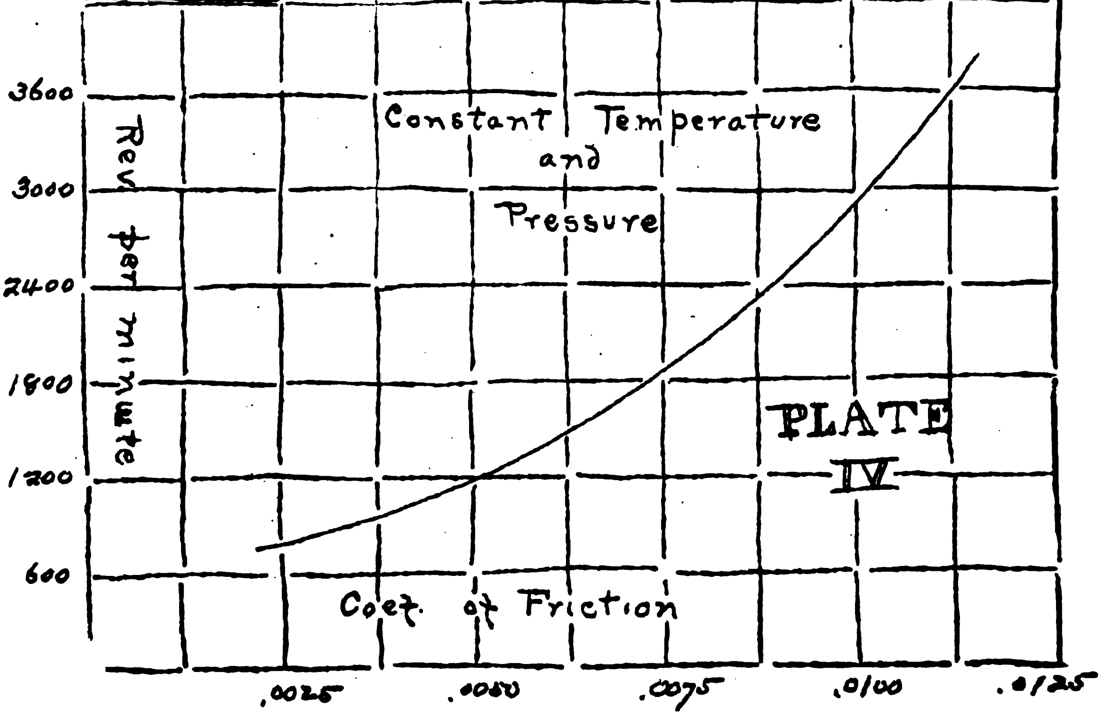


PLATE IV

temperature and pressure, at constant speeds. In taking these readings the desired pressure was put upon the journal, which was then made to revolve at a constant speed until the temperature of the journal ceased to rise. A reading of the theremometer was than taken. Here we observe the effect of pressure on temperature of journal for the different oils. Eng. Oil No. 3 giving the lowest temperature of journal for all pressures, and castor oil the highest of the samples tested This plate also shows the effect of speed upon temperature ; the three lower curves being produced under the same conditions as the upper ones, except that the speed was 1,200 rev. per min. instead of 3,000. That this increase of temperature is directly as the speed is shown in plate No. 2, where the temperatures are plotted with different speeds. The temperature rises practically in a straight line.

Plate No. 3 is of much greater interest. The results there shown were obtained at the same time as those on plate No. 1, but in this case we have used the coefficient of friction as an ordinate, instead of the temperature. In studying this plate it will be necessary to bear in mind that the temperature is variable and that it rises rapidly with an increase of pressure, or an increase of speed.

It will be observed that the coefficient of friction drops quite rapidly with the increase of pressure. It was observed during these tests that at a constant temperature the coefficient of friction increased under an increased pressure, and in a series of tests, (not shown), the coefficient of friction decreased rapidly under an increase of temperature. On plate No. 1 it is also observed that the temperature increases under increased pressure. The result is that with a constant speed under an increase of pressure the coefficient of friction is lowered more by the resulting increase of temperature than it is raised by the increased pressure, producing as we see in plate No. 3, the smaller coefficient of friction at the greater pressure.

Again if we will shift the curves produced at 1,200 rev. per min. to that part of the plate occupied by those produced at 3,000 rev. per min., we shall find that these two sets of curves almost coincide; that is to say, the coefficient of friction at any of the given pressures is nearly the same whether the speed is 1,200 or 3,000 rev. per min. This would seem to agree with a once believed law that friction was independent of velocity. We must look elsewhere, however, for an explanation. On plate No. 4 are shown the resulting coefficients of friction at different speeds at an attempted constant temperature. It was not possible to keep the temperature of the journal perfectly constant, but the results clearly show that there is an increase of friction with increased speed.

Plate No. 2 shows that an increase of speed causes an increase of temperature, and from results (not shown) an increase of temperture, a decrease of the coefficient of friction The result that there is very little change in the coefficient of friction, as shown in plate No. 3, indicates that the increase of friction due to increased speed is almost exactly balanced by the decrease of friction due to the rise of temperature, which is caused by the increased speed.

MAGNETIC PERMEABILITY OF SPECIAL IRONS. *

BY MILTON E. THOMPSON, PERCY H. KNIGHT, AND GEO. A. BACON.

During the last year or two there has been a marked change and improvement in the qualities of iron used in the construction of electrical machinery. It is now generally well understood that not only are the efficiencies of transformers, dynamos and motors increased by improving the quality of the iron used, especially where this iron is subject to changes of magnetism and consequent loss by hysteresis, but also that the capacity of any given machine will be greatly increased by improving the quality of the iron. Thus, in the majority of dynamos, the capacity of the machine is limited largely by the heating of the armature, and the greater part of the heat developed in an armature is usually produced in the core. If the heat developed in the core can be reduced by improving the quality of the iron used, enough extra current may be taken from the armature to balance this saving in the core. Again, in a dynamo or motor, the principal part of the weight of the machine is due to the field magnets. If the permeability of these field magnets can be doubled by improving the quality of the iron used for their construction, the weight of these magnets may be reduced in the same proportion. In many classes of dynamo machinery, as for instance, railway motors and marine dynamos, this saving in weight and the consequent increase in the capacity of a machine of given weight, is of

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* A paper prepared for the annual meeting of the American Institute of Electrical Engineers, held in Chicago, June 6, 7, and 8, 1892.

very great importance. It has long been known that the magnetic value of wrought iron is several times as great as that of cast iron; but the readiness with which cast iron may be moulded to the required shape for field magnets has kept it in favor for this purpose, in spite of its low permeability. A demand has arisen for a quality of iron which shall have high permeability and still possess the quality of being easily cast into the proper shapes for field magnets for dynamo machinery. Many attempts have been made to so improve the quality of cast iron, but for the most part with little or no success; and cast iron stands to-day as a metal having nearly the same magnetic value for any and all qualities, though some slight improvements have been effected by some makers, as will be seen later.

Attempts have also been made to produce castings from wrought iron, and lately with fairly good success. This is accomplished, in general, by melting down scrap wrought iron in crucibles, rendering it fluid by the addition of a small quantity of aluminium, and pouring as with ordinary cast iron. A great many extra precautions have to be taken to insure sound castings, and as a rule, the castings made from this "mitis metal," as it is usually called, are rough and somewhat difficult to work, on account of their toughness. These castings have shown themselves to be of very much higher permeability than cast iron, and have rapidly come into favor, especially in the construction of railway motors. Makers of steel castings have also been experimenting with a view to producing a metal suitable for field magnets of dynamo machinery. Some of them have been very successful in this undertaking, and steel castings for field magnets are to-day an undoubted success. Manufacturers of sheet irons have also been trying to keep up with their fellow workers in this line, and not a little experimenting has been done with a view to the production of better qualities of sheet iron.

The writers having recently made, in the laboratories of Cornell University, quite a number of tests of samples of various special irons from different manufacturers throughout the country, it was believed that some of the results would prove of interest to the general electrical fraternity.

The method used for these tests was a modification of that used by Rowland, the samples being prepared in the form of rings, and wound with two sets of windings, a primary and a secondary. The magnetizing current was passed through the primary circuit and measured by means of a Weston Ammeter. A ballistic galvanometer placed in the secondary circuit measured by its throw the magnetic induction due to any given change in the magnetizing current. Two different plans were tried in taking the curves and found to give slightly different results. The first was the reversal method, in which the current was commenced at its maximum value, and its direction reversed several times by means of a reversing switch, in order to bring the magnetism up to its full value, the secondary circuit being open. The secondary was then closed through the galvanometer, the current reversed, and the induction measured by the throw. The current was then slightly reduced, reversed several times as before, and the induction again measured on reversing the current. In this way the magnetizing current was gradually reduced to zero, and from the data thus obtained curves were plotted with magnetic lines per square centimeter for ordinates and magnetizing force for absissae. In the other method, which was used for taking most of the curves, and which gives results more nearly like those obtained by Hopkinson and which are generally accepted as standards for wrought and for cast iron, the sample was first completely demagnetized. In some cases this was done by simply reversing the current through the primary and at the same time gradually reducing it to zero.

By this method, however, no samples except those composed of sheet wrought iron were successfully demagnetized, which might suggest that the Foucault currents set up by the reversed current in the samples of solid iron tended to hold up the magnetization. An alternating current of both high and low periodicity was also used unsuccessfully, and it was only by finally heating the samples to a cherry red heat and allowing them to cool in air, so as not to change materially their softness, that total demagnetization was obtained. The check used to determine demagnetization was the symmetry of the two halves of the hysteresis card as to the axis of magnetizing current. The sample being demagnetized, a small current was passed through the primary, and the induced magnetism measured by the throw of the galvanometer. The current was then slightly increased and the deflection of the galvanometer again noted. And so on up to the maximum magnetizing force, the current being gradually increased step by step. The current was then reduced step by step to zero, reversed, and increased step by step to a maximum equal to that of the other direction. The descending and reversal curve was taken simply to serve as a check upon the observa-

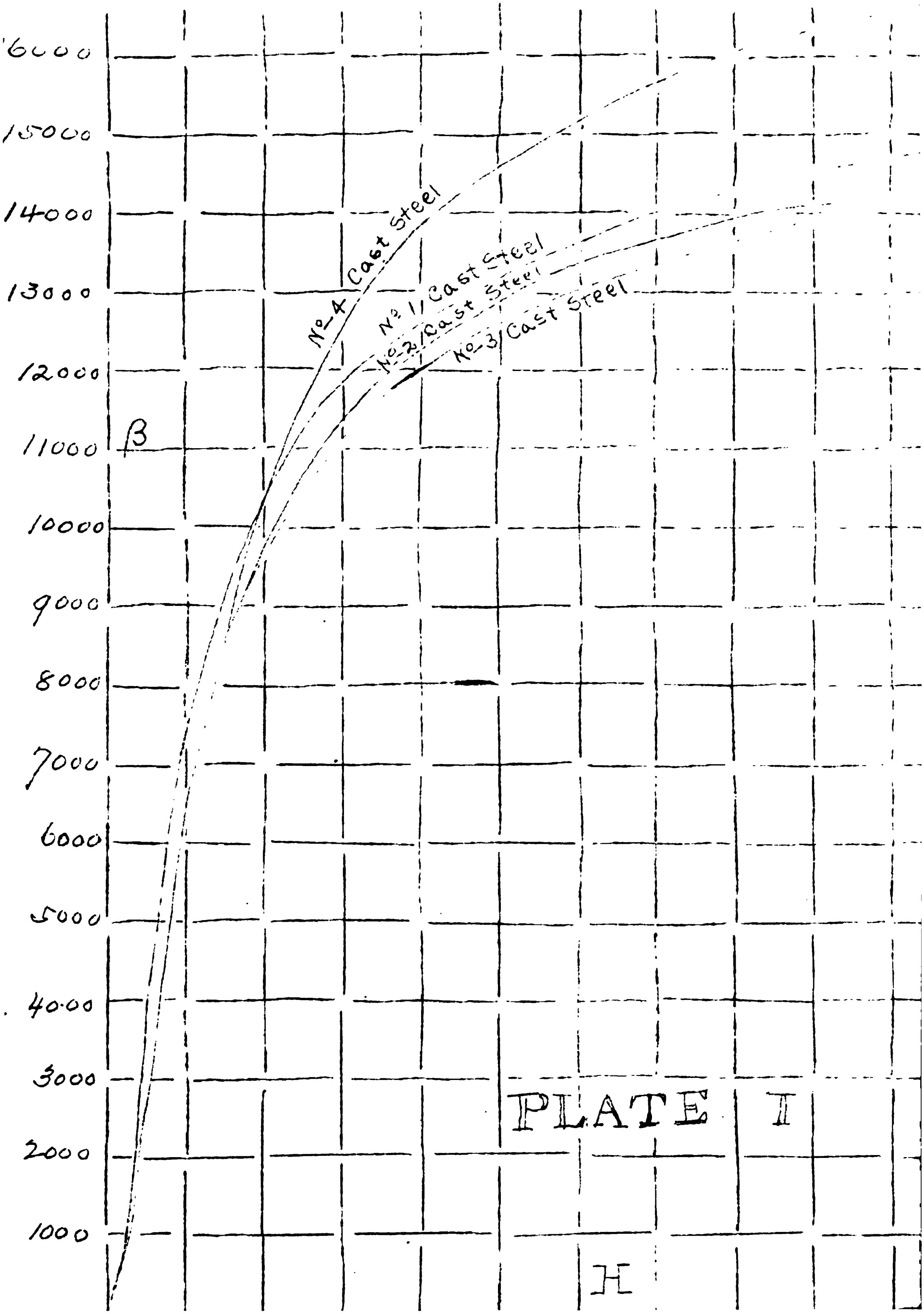
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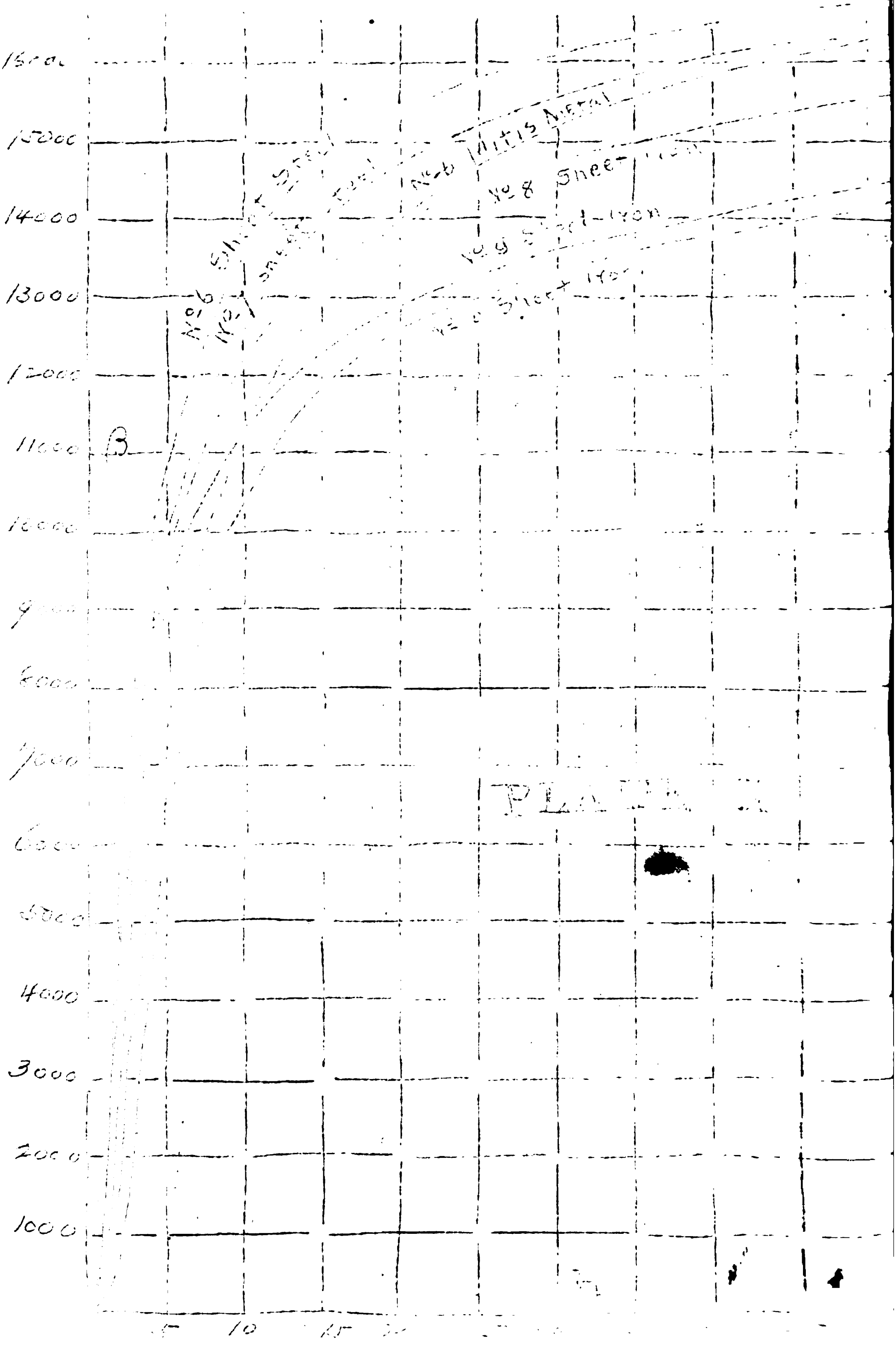
PLATE I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No 8 Sheet Iron
No 9 Sheet Iron
No [illegible] Sheet Iron
PLATE
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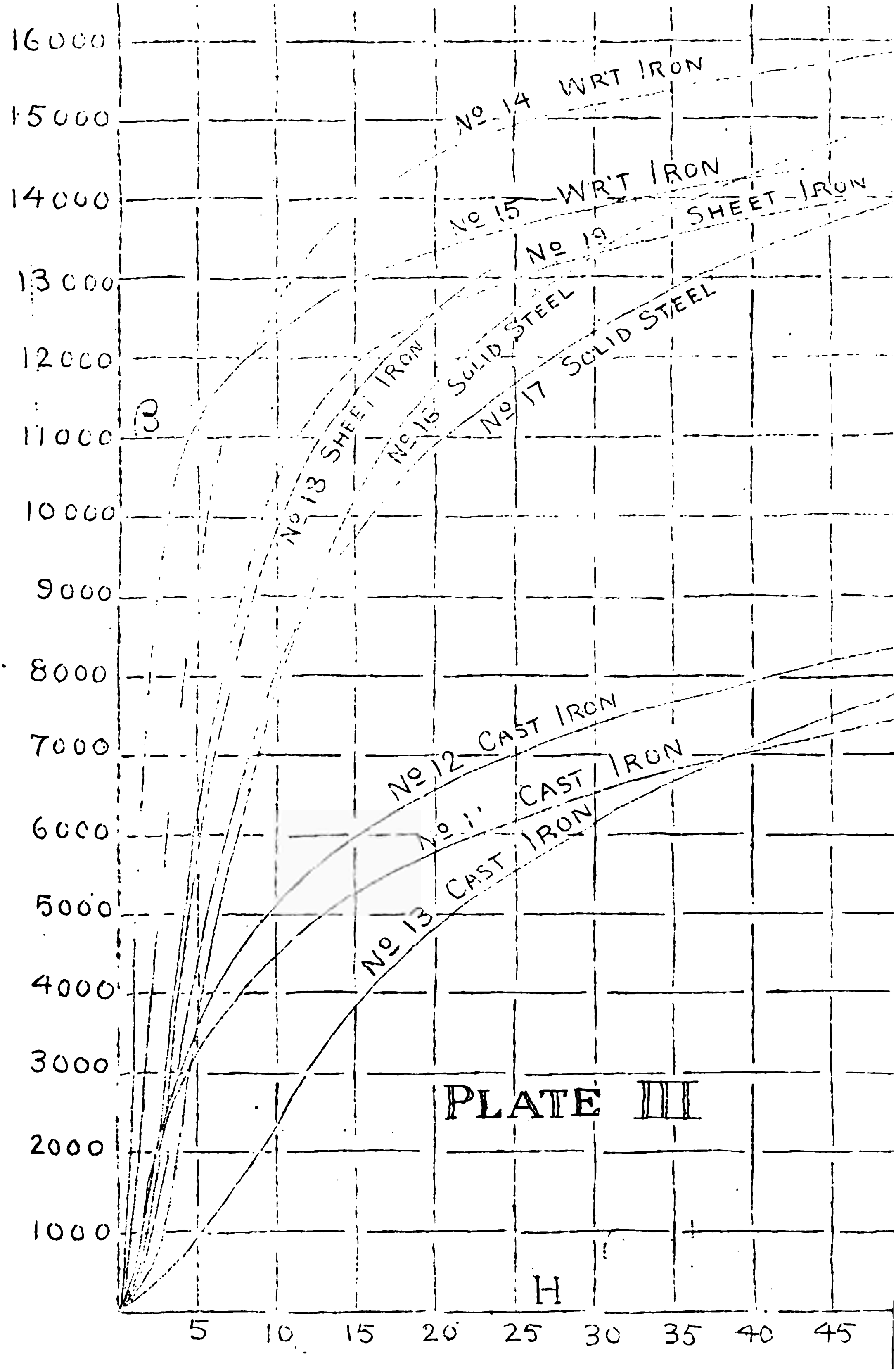
tions of the ascending curve and only the latter was plotted. Curves obtained from the same sample by the reversal method and by the step by step method were found to differ from each other by eight or ten per cent. at maximum values, the curves by the reversal process reaching the higher values. The magnetization of field magnets of dynamo machinery would probably reach values higher than that given by either of these methods of testing, for the iron being subject to vibrations from the rotating armature, and being at the same time under a continuous magnetizing force, would no doubt reach as high magnetic values as could be obtained by any method of testing.

The results obtained are embodied in the accompanying curves, which present the results of tests on samples of iron from twelve different companies, in many cases a large number of different samples of the same kind of metal having been tested. Referring to these curves :—Plate I presents curves of four samples of steel castings from different companies. The curves show the samples to be of very good quality. Curves No. 1 and No. 2 being the results of a single run while No. 3 is an average curve of about a dozen different samples of steel castings furnished by one maker, and No. 4 an average curve of two samples of steel castings furnished by another company. The different samples represented in curve No. 3 did not differ very materially from one another, and there was but a very slight difference in the two samples represented by curve No. 4. Curves No. 1, No. 2, and No. 3, were taken by the step by step method, while curve No. 4 was taken by the reversal method, which will account for the high value of this curve, in a measure, though it is very probable that the quality of the steel represented by No. 4 was slightly better than that of the other samples. Of the curves on Plate II, No. 5, No. 6, and No. 7 were taken by the reversal method while No. 8, No. 9 and No. 10 were taken by the "step" method. Curve No. 5 is the average of two different samples of wrought iron castings from the same maker, the two samples, prepared at different times and from different pourings, showing almost identical qualities. The magnetic value of mitis metal, as shown by curve No. 5, differs very little from that of steel of good quality, as shown by curve No. 4. Curves No. 6 and No. 7 are from two samples of sheet steel of somewhat peculiar manufacture, inasmuch as they are said to contain no manganese ,that element being perhaps the most objectionable impurity in mild steel, so far as its magnetic properties are concerned. The two samples from which the curves were taken were made as an experiment, and by slightly different processes. Curves No. 8, No. 9 and No. 10 of Plate II are from three different samples of sheet iron used for armature cores and transformers by three well-known electrical companies. Neither of these is up to the values given by Hopkinson for good wrought iron, but the difference in the method of taking the curves may account for their being lower. Curves No. 11, No. 12 and No. 13 of Plate III, are from three different samples of cast iron, used by three electric companies for field magnets of dynamo machinery. Sample No. 11 is an ordinary quality of cast iron, and differs from the values given by Hopkinson for cast iron by only an inappreciable quantity.

No. 13 is rather peculiar, in that for high values of magnetizing force it is slightly better than ordinary cast iron, while for low values it is much poorer. Its magnetic properties are more like those of very hard steel, than of cast iron. No. 12 shows a metal whose magnetic value is from ten to fifteen per cent. higher than ordinary cast iron, the curve still keeping its same general shape. This sample would seem to indicate that there *is* such a thing as improvement in the magnetic qualities of cast iron. Curves No. 14 and No. 15 represent two different samples of wrought iron, used by two electric companies for field magnets. These curves were taken by the reversal method, and indicate for the metals a value somewhat below that of the best wrought iron. Curves No. 16 and No. 17 are both from the same steel casting, and show the difference between the step by step method and the reversal method. No. 16 is by reversal and No. 17 by step by step. Curves No. 18 and No. 19 are both from one sample of sheet iron, No. 18 being taken by the reversal method, and No. 19 by the step by step. A similar difference in the two methods is indicated by these two curves. Plate IV is an attempt at a comparison of some of the most important of the curves mentioned above. Curve No. 20 is Hopkinson's curve for wrought iron. No. 23 is an average curve for steel castings as made by four different companies. No. 21 is a good quality of steel casting, by the reversal method, and No. 22 is an average of mitis metal, by the same method. No. 24 is Hopkinson's curve for cast iron; and No. 25 is an extra quality of cast iron. It will be noted that this iron is quite an improvement over the ordinary cast iron, which would seem to show that there is still a chance for the standard of cast iron to be raised.

A comparison of curves No. 20 and No. 23 shows that the mag-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No 14 WR'T IRON
No 15 WR'T IRON
No 19 SHEET IRON
No 13 SHEET IRON
No 15 SOLID STEEL
No 17 SOLID STEEL
No 12 CAST IRON
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No 13 CAST IRON
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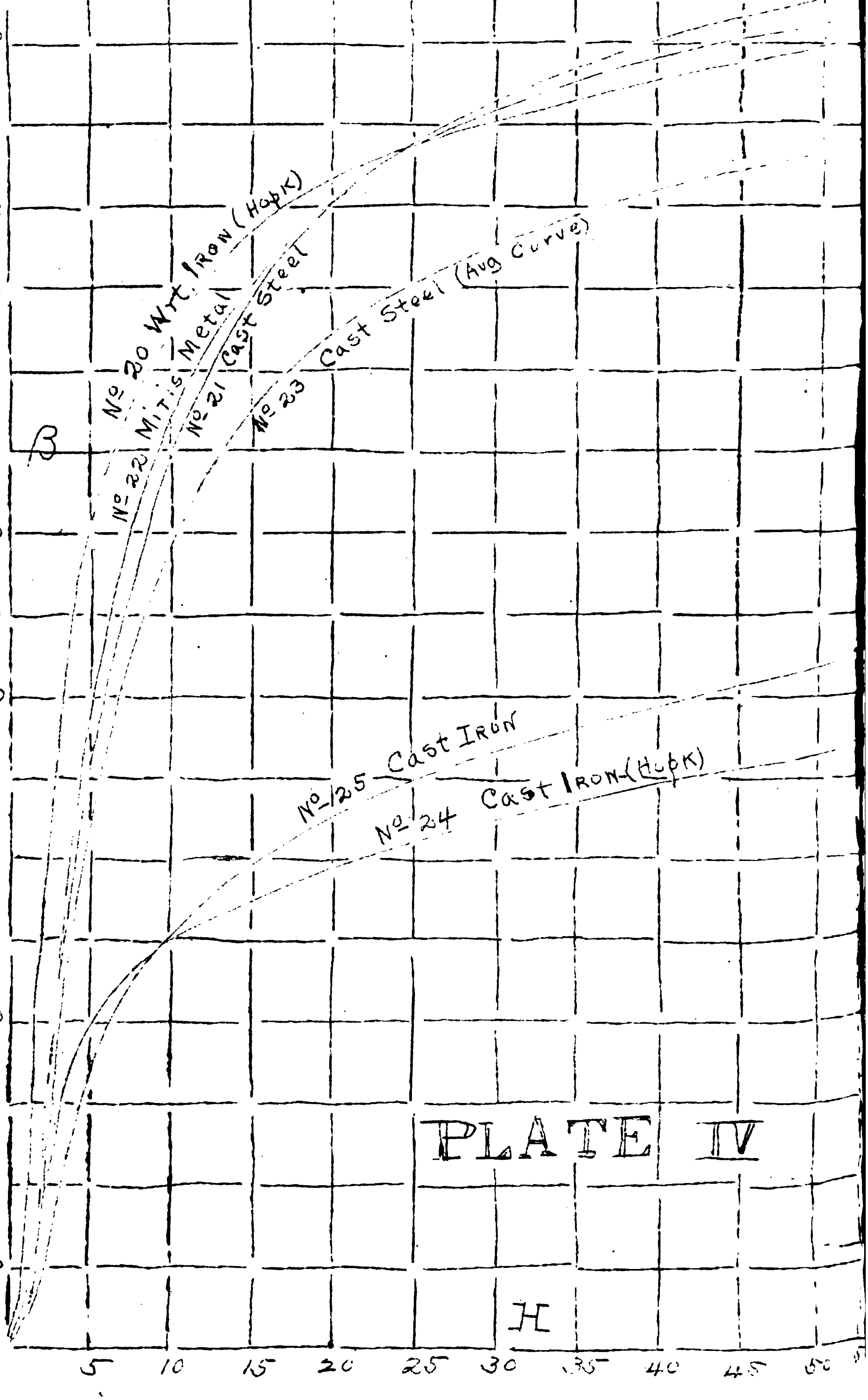
PLATE III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50
No 20 Wrt. Iron (Hopk)
No 22 Mitis Metal
No 21 Cast Steel
No 23 Cast Steel (Avg Curve)
No 25 Cast Iron
No 24 Cast Iron (Hopk)

PLATE IV

netic value of the average steel casting is only about eight per cent. below that of the best wrought iron, and from curve No. 21 we might infer that it would be perfectly safe to use for the best steel castings the magnetic values given by Hopkinson for wrought iron. Comparing curves No. 21 and No. 22 we see that there is practically very little difference between the magnetic value of steel castings of the best quality and mitis castings, and there seems to be no good reason for believing that the former cannot be made of quite as good quality as the latter. Comparing both of these metals with curve No. 24, their magnetic values are so far superior to that of cast iron that it seems quite certain that only the cost of production can stand in the way of their rapid and almost universal introduction for field magnets of dynamos and motors. When we consider that the cost of steel rails is but little different from that of cast iron, it seems reasonable to suppose that when the art of producing steel castings comes to be better known and more fully understood, and better facilities are provided for their manufacture, such castings can be produced at a cost but little in excess of ordinary cast iron. Considering then the great superiority of cast steel over cast iron for electrical purposes, it seems safe to predict that the day is not far distant when steel castings will almost entirely replace cast iron in the construction of dynamo machinery, and the improvement in such machinery resulting from this change will be perhaps one of the greatest steps that has ever marked the progress of the electrical industry.

OPTICAL CALORIMETRY.

BY E. H. WOOD AND J. H. DYETT.

This work was begun with the intention of ascertaining whether either of the three phenomena, refraction, absorption, or polarization of light could be made the means of determining the quality of steam.

To measure the deviation due to passing a ray of light through steam a cast iron prism was constructed. A hole drilled between two of the vertical faces and having the ends covered with glass plates, furnished the chamber for the steam, which was admitted and exhausted through two holes drilled in from the third face. The light from one filament of an incandescent lamp was passed through the steam prism, and an image of the filament was produced on a field scale 16 ft. distant, by means of a long-focus lens. This image was seen to slightly change position with varying pressures and qualities of steam ; but the range of variation at our command was only 30 pounds and 1 per cent. on either side of saturation, respectively.

These narrow limits of quality were fixed by the collecting of moisture on the glass on the one hand, and melting of the rubber packing rings with superheated steam on the other. It was therefore decided to try the second method as offering a more probable means of securing the desired end. This was to measure the absorption of a ray of light due to its passage through steam.

A tube to contain the steam was constructed of pipe fitting ; the windows being screwed into the ends some little distance, to keep them free from condensation. The distance between them was about 4 ft. The method of measuring the light absorbed by the steam was by comparing illumination on the two surfaces of a mirror.

The intensity of the light passing through the steam was compared with that coming directly from a similar source by means of a spectro-photometer. This instrument has recently been devised by Professor Nichols and was described in the last issue of the CRANK.

The absorption was marked. In some cases it amounted to nearly 40 per cent of the total light, and was principally in the violet end of the spectrum. Moreover it increased very measurably with the pressures and was delicate enough to show, in the majority of cases, changes of quality as small as one-tenth of 1 per cent. Here again the attainable limits of quality were about 1 per cent. wet or superheated, but these in the writers' opinion might be greatly increased by more efficient jacketing of the windows.

The polarization method in many respects seems more likely to give a practical working calorimeter. Unfortunately time did not permit an experimental treatment of this method, but an apparatus was constructed, and some of the details determined upon. In place of the long steam tube a very short one is used, capped as before with the T's containing observation tubes. A third tube and window is then inserted at right angles mid-way between the T's, the other steam connections being the same as before.

Light is passed from any suitable source into the apparatus and striking the particles of water held in suspension by the steam, is partly reflected at right angles; this reflected light has been found to be polarized.

Thus a portion of the polarized beam will pass through the third tube, and its brightness may be compared with that of another beam from the same source reduced by passing through an adjustable diaphragm. The adjustment being made by means of a screw with graduated head, the number of turns may be made a measure of the quality.

TEST OF A HIGH SPEED STEAM YACHT.

In the test of the "Clara," (which was kindly put at the disposal of the writers by Mr. Chas. Kellogg, of the Elmira Bridge Works), an attempt has been made towards a solution of all these problems. A description of this graceful yacht is hardly necessary. She has an enviable reputation for beauty and speed in other waters than Cayuga Lake.

The work previous to the actual test consisted of (1) "lifting off" the yacht's lines for the purpose explained below, and (2) the computations depending on these measurements. The first has reference to the method of making drawings which show the proportions and form of the yacht's hull. There are three views of a ship usually shown, the "sheer," or side view; the "body," or end view; and the "half breadth," or top view. Having these "lines," one could construct an exact duplicate. They also give the basis for the computations when the ship is considered merely as a floating body; as, for instance, in the calculations for displacement, center of buoyancy, metacenter, areas of midship sections, wetted surface, and stability, only mention of which lack of space will allow.

After these calculations were concluded the experimental part of the work began. The relation of power to speed, mentioned above, was first taken up. A course of 2.38 miles was surveyed between Garrett's and Crow Bar Points, on Lake Cayuga, and ranges were placed. The yacht was now run over this course at different speeds, the exact time being taken for completion, and the engine was "indicated." (The engine is a triple expansion 7½, 12, 19, and a 10½" stroke.) From this data points on the curve were determined.

During another day a complete engine and boiler trial was made to determine the efficiency of both. A peculiarity of the system is the condenser, which consists of a long copper tube, lying outside the yacht, in the the angle between the bottom and the keel. The water in the lake thus becomes the condensing medium.

The boiler is vertical, fire-tubular, of recent construction, and Mr. Kellogg's design. It has more than the ordinary number of tubes, and gives dry steam and quick action. The quality of steam, and high efficiency, speak for themselves as to the design.

The wave outlines made by the yacht in her passage through the water were taken at the speeds attained. They were measured by dropping a graduated rod from a fixed point on deck to the surface of the water. This was done at intervals along the deck and the wave outline thus shown. Photographs were taken in addition, to give an idea of the waves away from the yacht, which were not measured by this method.

The pitch of the screw, the stopping and turning power of the yacht, her period of rolling, and the position of the center of gravity, were all observed by actual trial. This latter was essential in calculating the stability, or force (as a moment) acting to right the ship at varying degrees of tipping.

Some of the results of the test are given below :

Displacement at	3′ draft,	4′ draft,	5′ draft.		
	17.9 tons,	33.7 tons,	52.6 tons.		
Wetted surface at	3½′ draft,	4½′ draft,	5′ draft.		
	973.6 sq. ft.	1074.4 sq. ft.	1274.98 sq. ft.		
Center of Buoyancy above keel at	3 ft.,	4 ft.,	5 ft. draft.		
	2.24 ft.	2.86 ft.	5.04 ft.		
Metacenter above C. of B. at	3 ft.,	4 ft.,	5 ft. draft.		
	3.22 ft.	2.78 ft.	2.04 ft.		
Stability in foot-tons at 4½ ft. draft.	20° heel,	40°	60°	80°	90°
	39.2 ft. tns.	71.6 ft. tns.	86 ft. tns.	57 ft. tns.	32.3 ft. tns.

I. H. P. at 15 miles per hr., 88½.

Quality of steam, 98 per cent. dry.

Evaporation per pound of coal, 11.19 lbs.

Water per I. H. P. per hr., 17.77.

Fuel per I. H. P. per hr., 1.99 lbs.

Efficiency of boiler, 72.3 per cent.

Mean boiler pressure, 109 lbs.

Cruising speed, 15 miles per hour.

The "Clara" can be stopped in two and one half times her own length, from the cruising speed of 15 miles per hour, and turns in a circle whose diameter is 12½ times her length.

In conclusion, it can only be said that the "Clara" is a very close approximation to an ideal steam yacht; and being a distinctively American product, it speaks hopefully for the future of ship and yacht building in this country.

TEST OF BUFFALO STREET RAILWAY.

On April 22d, an efficiency test of the engines and boilers of the plant of this company was made by A. B. Clemens and T. W. Voetter assisted by a party of Sibley College students.

The power station of the company is situated on Niagara street, on the banks of the Niagara river, and near the tracks of the N. Y. C. & H. R. R. R.*

At present there are in place two batteries of Babcock and Wilcox water tube boilers. These are equipped with the Roney mechanical stoker, while on the way to the chimney the still hot furnace gases pass through Green economizers in which the feed water is heated. Foundations for a battery of the Scotch type of marine boilers are being laid.

The coal is brought in small dump cars running on a trestle which extends from a siding of the railway into the boiler room. An electric motor furnished the power for drawing the loaded cars into the building.

The engines at present installed are three 250 H. P. Ball horizontal cross compounds, and two 500 H. P. vertical engines built by the Lake Erie Engineering Works. A cut of this type of engine and a brief description will be found in the CRANK for March.

The generators are of the Edison type, two of the Ball engines being each belted directly to a 150 K. W. dynamo, the third Ball engine belted to one of 175 K. W. capacity. The Lake Erie engine furnished power for one 150 and one 175 K. W. generator.

When the Conover jet condensers, now being installed, are completed it is proposed to substitute 200 K. W. generators for the above.

The feed water is at present drawn from city mains and driven through Goubert heaters and thence through the economizers into the boilers by Barr tandem compound duplex pumps. A Stratton separator is attached to the steam pipe leading to each engine.

The test of the engines began at 6 a. m. and ended 11:25 p. m. The boiler run commenced at 12:40 p. m. and ended at 11:40 p. m. Throttling calorimeters were placed over the boilers and above one of the separators. A separating calorimeter was placed on the exhaust pipe of the Lake Erie engine. Observations were made and cards taken every fifteen minutes throughout the run. Readings were taken at the same time, on a Weston voltmeter and an Edison bus-ammeter.

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*See lecture on Electric Railway Construction, by C. J. Field, M. E., in March CRANK, Vol. VI, No. 6.

The test was made non-condensing and some of the results are given herewith.

Duration of boiler trial	11 hrs.
Fuel burned per hour dry	2943
Percentage of ash	11.3
Combustible per hour	2611
Moisture in coal	2.4 per cent.
Kind of coal	Semi-bituminous screened nut. Reynoldsville, Pa.
Square feet of heating surface, 3 boilers	8251.8
Total water supplied per hour	27557.4
Quality of steam	97.3 per cent.
Dry steam per hour	26813.4
Equiv. evaporation from and at 212 degrees	28274.6
Temperature of feed water	167.13
Dry steam per lb. of coal	9.11
“ “ “ “ from and at 212 degrees	9.60
“ “ “ “ combustible	10.27
“ “ “ “ from and at 212 degrees	11.02
H. P. (34.5 lbs water evaporated from and at 212 degrees per hour)	819.8
Builder's rating	720
Percentage above	13 per cent.
Efficiency of boiler	74.5
Temperature of feed from mains	38.3
Rise of temperature in heaters and economizers	138.8
Average I. H. P.	674.4

MAGNETIC PROPERTIES OF ALUMINUM—IRON.

By C. Eickemeyer.

The pieces of metal tested magnetically contained ½ per cent. and ⅛ per cent. aluminum respectively alloyed with cast iron. The Eickemeyer Differential Magnetometer was used in making the tests. The action of the instrument is based on substantially the same principles as the Wheatstone Bridge, but instead of the two electric currents of the latter, two magnetic circuits are made use of. The two magnetic circuits, when balanced, produce no effect upon the indicator, but when there is a greater magnetic resistance in one branch than in the other the needle is deflected.

The instrument in its simplest form, consist of two horse shoe magnets which are clamped on an upright piece of wood with their poles of like denomination facing each other. In the center between the four poles, is mounted a soft iron indicator needle provided with a pointer, back of which is a graduated arc, for convenience divided into degrees.

If a card board be placed over the magnets and iron filings sprinkled upon it, the filings become temporary magnets which show the direction of the lines of force; thus showing that like poles repel each other. The lines of force from the magnets run from unlike pole to unlike pole, but where the lines of force of the magnets come in contact with each other a straight line is found. It is evident that a short needle of soft iron or steel will set itself in this line, which for convenience we will call the zero line, and the corresponding mark on the scale zero.

If a piece of iron is placed diagonally across, thereby connecting two of the unlike poles, the N pole of one magnet to the S pole of the other, in the first case the lines of force in both magnets had to complete their circuit through the air but now some of the lines of force pass from the N pole of one magnet through the piece of iron to the S pole of the other magnet, while the open poles have to complete their circuit through the air as before. If a card board is now put over the magnets again the lines of force will arrange the filings as to show their path, which will be from a pole in one magnet to an unlike pole in the other magnet. The needle following the direction of the lines of force of the two free poles completing their circuit through the air.

To bring the needle to zero the two free poles have to be connected with a piece of metal of the same conductivity as that first connecting the two unlike poles. We thus have a simple device for comparing the different pieces of metal. Let us suppose we have two pieces of iron of the same cross section, both fitting nicely upon the sides of the poles of the magnets; if then we find, when both are placed on the poles, the one connecting one pole of a magnet to the unlike pole of the other, and the other piece of metal connecting the remaining poles, that the needle remains at rest, we know that the two pieces of iron carry the same quantity of magnetic current or lines of force. Should the needle still be deflected from the perpendicular, we would know that the piece, having the same direction as the needle, has the least conductive capacity and the extent of this deflection would form a means to measure the difference in value of their magnetic conductivity.

But there are other means of comparison. Suppose we have a number of pieces of iron of known cross section, and we add to the bad conductor until the needle returns to zero, then the pieces added will represent the difference between the two conductors. The instrument in its modern form consists of electro magnets, whose current is measured by ammeters and regulated by resistance.

A preliminary test showed that the magnetic properties of aluminum-iron differ so little from those of ordinary cast iron that it was necessary, in order to determine any difference whatever, to reduce the castings to standard size. The test was made by balancing the Aluminium-Iron with a test piece of Norway iron, the magnetic characteristic of which is known.

The Al-iron was not compared directly with the standard Norway iron, but to reach a greater exactness in determining the difference between ordinary cast iron and the samples of Al-iron, first, a sample of ordinarily good cast iron was tested by comparing it with the standard Norway iron, thereby determining its magnetic characteristics. The Al-iron was then compared with this sample of ordinary cast iron and the difference between both determined.

This method eliminates the influence of remanent magnetism, to a greater part in the comparative tests, thereby increasing the accuracy and also serving as a check upon the work, since the piece of ordinary cast iron had been tested before. In the comparisons made the piece containing the smaller percentage of aluminum proved to be superior to the one containing the larger percentage of aluminum in the cast irom. From which we can state that the addition of aluminum has no very marked influence upon the magnetic conductivity of cast iron, but slightly decreases its permeability.

THE DEMANDS OF THE STATE.

BY R. H. THURSTON.

The needs of the people constituting the State were made the subject of investigation by a Commission of the State of New Jersey, some years ago, and the commission created for this purpose in making its report, presented a plan for the encouragement of manufactures, prepared at their request by the secretary of the commission, Professor Thurston. This report, printed as public document, was never formally published and has been but little known outside the state in which it was called for, and, as it contains many points of general importance and interest, we give in the following pages, some extracts from its more suggestive passages.

The prosperity of the people of any State—in all qualifications and all natural advantages being the same—is the greater as the labor of the producing classes is increased; and the value of labor is the greater as the products of labor are more largely resultant from the operations of tactual or mechanical manipulations which are guided by highest skill or directed by artistic talent.

It follows at once that the cultivation of skilled industries and of industrial art, are, at least, very greatly, if not principally, to be relied upon in the effort to promote the highest prosperity of a people.

In a State in which both agriculture and manufactures are naturally favored, the highest prosperity is further promoted by seeking to secure such a relation of the agricultural to the manufacturing population as will most fully develop agricultural resources and lead to the expenditure of the earnings of each class among its own neighbors.

Exceptions to the rule exist where articles desired can be obtained most cheaply elsewhere in consequence of natural and inartificial advantages favoring their production abroad. For example, the attempt to raise tropical, or even semi-tropical products of agriculture in New Jersey, even where it might be possible, would be unwise, since the labor demanded could be made more productive if expended in raising cereals and other plants which are well adapted to our soil, and by then effecting their exchange for the products of a warmer region.

To secure the best social and commercial condition of our people, it is thus advisable to ascertain the nature of our soils, climate and other natural conditions, to learn what agricultural and manufactured products can be made to give the best return for labor and capital invested, and then to secure the highest possible proportion of labor, skilled and artistic, in the working up of raw materials and the production of fine goods, and to effect an exchange of all products of the labor of our own people among themselves, and thus to bring producer and consumer into the closest possible relations.

Since the encouragement of the manufacturing industries is the most direct and most lucrative method of increasing the wealth of a community, all nations and all States are striving to absorb the greatest possible proportion of those industries which produce that comparatively fixed and definite quantity of manufactured products which only the world can, at one time, consume.

As this amount is always limited by the demands of a certain part of the total population of the world, there is constantly in progress a sharp, and often desperate, competition for the control of the market.

In this competition, those States and those nations will be most successful, and most independent of commercial and financial changes, whose industries are most largely skilled industries, and are most varied in their character. The products of the most highly skilled labor are in demand, even when unskilled labor finds no market; and where there exist a multiplicity of industries, the probability of general depression arising from the not infrequent depression, or entire extinction of any one branch, is so much the less. It is also an important consequence of the policy which leads a State to cultivate those branches of manufactures which demand the highest skill and greatest talent, and to encourage a varied industry, that the waste of labor and of capital in transportation and in coarse work is reduced to a minimum. The most is thus made of every pound of metal or of textile material brought, raw, into its markets, and the highest prices are secured to the agriculturist and to all producers of native raw materials, whether agricultural or metallurgical.

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For many years European nations have been steadily, systematically and intelligently carrying out a policy, which is as admirable as it is successful, looking to the encouragement and support of all branches of industry in the most effective possible way, by rendering the artisan and the laborer more intelligent and better informed; not simply offering him general knowledge through a system of general education in the common or public schools, but teaching him the essential principles which underlie the practice of his art, and supplementing in trade schools this directly practical education by the still more practically useful and immediately applicable knowledge of the manipulations peculiar to his work.

The only way in which to compete with the conditions introduced by this statesmanlike and most enlightened policy is evidently the adoption of a similar policy, and, if possible, a more complete and extended application of the methods dictated by it than has been elsewhere attempted. A technical education and trade schools adapted to nearly every important branch of industry have long formed a part of the European system of aid to manufactures, it is evident that successful competition in future years is not likely to prove satisfactorily successful unless the task of overtaking our competitors in a race in which they have many years the start of us, and in which they have already acquired every advantage that such a start and the gain of experience derived by the progress of a full generation can give, is very promptly commenced and very energetically and intelligently prosecuted. Our people are, and always have been, largely dependent upon artisans imported from abroad for aid and direction in every branch of industry in which extraordinary skill, taste or acquired knowledge of technical details is demanded. We only become independent by supplying ourselves with the means of similarly training our own workmen.

A "plan for the encouragement of manufactures of ornamental and textile manufactures," to be effective and to be of lasting benefit to those industries, must include, primarily, some practical scheme of education and of industrial instruction and training that shall render the working people engaged in those branches the equals, if not the superiors, in intelligence, skill and knowledge, of the same class in any other country. Such a plan must include a general policy of encouragement of every effort to introduce new divisions of work and to diversify existing established industries. *No restricted scheme or narrow policy can be of great or permanent benefit.*

A general plan, including such modifications of the early education and the latter training of the rising generation of artisans and laboring people as shall especially prepare them for a life of intelligent and prosperous labor in the dapartments to which the attention of the Commission has been particularly called, will, with little modification and at but slight additional cost, equally well assist in the development of all branches of domestic manufactures and of our agricultural interests as well. It would also be impossible to distinguish, in the early training of youth, those who were ultimately to adopt the pursuits that were the objective of the preparatory work of any certain kind from those who were to follow an occupation requiring a somewhat different preparation. It would seem, therefore, best to endeavor to devise a plan by which the studies and training of youth should be, as completely as possible, introductory to all the industries, and which should defer a special training to be given in trade schools to a later period when the direction in which the pupil is to work through life has been fully determined.

Such a plan to be perfectly successful and most completely effective, must evidently aim at making this early training available to the people of the State to the full extent to which such training is given elsewhere to-day, or is likely to be given in any competing district during the future. It is only when our whole population shall have been made as intelligent, as well informed, and as well skilled in every department which bears upon the industries, existing and prospective, of the State, as any other people can be, that we shall be able to rely upon securing the advantages due to our natural position and resources.

As will be presently seen, such a plan, to be satisfactorily complete, must comprehend:

(1). A common school system of general education, which shall give all young children tuition in the three studies which are the foundation of all education, and which shall be administered under compulsory law, as now generally adopted by the best educated nations and states on both sides of the Atlantic.

(2). A system of special adaptation of this primary instruction to the needs of children who are to become skilled artisans, or who are to become unskilled laborers, in departments which offer opportunities for their advancement, when their intelligence and skill prove their fitness for such promotion, to the position of skilled artisans. Such a system would lead to the adoption of reading, writing and spelling books, in which the terms peculiar to the trades, the methods of operation and the technics of the industrial arts should be given prominence, to the exclusion, if necessary, of words, phrases and reading matter of less essential importance to them.

(3). A system of trade schools, in which general and special instruction should be given to pupils preparing to enter the several leading industries, and in which the principles underlying each industry, as well as the actual and essential manipulations, should be illustrated and taught by practical exercises until the pupil is given a good knowledge of them and more skill in conducting them. The series should include schools of carpentry, stone cutting, blacksmithing, etc., etc., weaving schools, schools of bleaching and dyeing, schools of agriculture, etc., etc.

(4). At least one polytechnic school, in which the sciences should be taught and their applications in the arts indicated and illustrated by laboratory work. In this school, the aim should be to give a certain number of students a thoroughly scientific education and training, preparing them to make use of all new discoveries and inventions in science and art, and thus to keep themselves in the front rank.

(6). A system of direct encouragement of existing established industries by several legal and proper means, as by the encouragement of improvement in our systems of transportation, the relief of important undeveloped industries from state and municipal taxes, and even, in exceptional cases, by subsidy. It is evident that such methods of encouragement must be adopted very circumspectly and with exceedingly great caution, lest serious abuses arise.

(7). A system of general supervision of the industries of the State by properly constituted departments of the state government. This system should comprehend, perhaps, a Bureau of Statistics, authorized, under the law creating it, to collect statistics and information relating to all departments of industry established, or capable of being established in the state, and to publish such information and statistics in circulars for general distribution, and in a report to be made to the State Legislature, annually, with the Governor's message.

The extent to which the measures here proposed may be expected to benefit the people of the State will, as a matter of course, depend upon the completeness and thoroughness of the plans adopted in carrying them into effect, the intelligence and knowledge as well as the energy of those to whom their prosecution is entrusted, and the capacity of the people to comprehend and to take advantage of the opportunity for self-improvement thus offered them and their inclination to avail themselves of it.

The extent to which the preliminary scheme of education adapted directly and peculiarly to the wants of the children of the artisan may be put into operation and the promptness with which the people may be enabled to profit by it will be determined wholly by the promptness with which legislators frame and school authorities enforce the required legislation.

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The foundation of trade schools can only take place through the direct action of the state government, and at the expense of large appropriations from the treasury of the state. The promptness and liberality exhibited in their establishment will be a measure both of the intelligence and enterprise of our people and their representatives, and of the magnitude of the benefits, absolute and comparative, to be gained by their foundation.

In this matter nearly every European state of any respectability and importance, and nearly every city of considerable magnitnde is far in advance of us and possesses a consequent advantage which even such prompt and determined action on our part as distinguished Great Britain when,—nearly a quarter of a century ago,—her people first awoke to a consciousness of the fact that she was as far in the rear as are we to-day, cannot soon compensate. With all Europe a generation in advance of us, it is sufficiently evident that we cannot act too quickly or too earnestly.

All the undeniably great advantages possessed by a new country, in mineral resources, large cultivable areas of rich soil, a wide range of climate and a system of government which awakens every power, mental or physical, of a people, cannot avail in a srtuggle with nations still richer in both knowledge and wealth and possessed of every facility for their immediate utilization by the coming generation as well as by that now existing.

It is here that we are farthest behind; and it is just here that we are in danger of acting least promptly and least effectively in the endeavor to place ourselves in a creditable relation to the world.

The establishment of artisan trade schools in every city in the state is of the most immediate importance, and the foundation of advanced schools of this character, in connection with the higher educational institutions of the State, is probably the most certain method of retaining maximum efficiency in the whole system, both by the preparation of young men and women for the most advanced and responsible positions in industrial establishments, and by supplying the minor schools with talented and well trained instructors.

It has been shown that to crown this whole system of industrial education and training, a polytechnic school is needed, in which the sciences and their most direct and useful applications should be taught by professors, each distinguished in his specialty and competent to expound the facts, principles, systems and theories of the latest and best authorities of the world, and to teach their most subtle refinements and explain their most abstruse investigations with that clearness and accuracy which comes of real learning.

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Having thus, very briefly, sketched the outline of a complete system of education and training, such as is needed to make a population thoroughly intelligent and most completely and practically efficient producers of wealth, as well as to give our artisans a maximum of comfort and independence, to most effectively extend and diversify the industries of the state, and to make the proportion of skilled to unskilled labor the highest possible, it will be instructive to study the work already done and in progress elsewhere, in order to learn just how we stand to-day, and how other people are working and what methods they find successful, and then to be able to form some idea of the probabilities of our being able to hold our own in the future, and to judge what hope we may have of gaining upon those who are now so far in advance of us.

A system of education, having for its object the preparation of artisans and laboring men to do their life's work with intelligence, skill and economy, rendering all available knowledge subservient to the successful prosecution of their work, is not of recent origin. It was proposed by the most learned men of earlier times, long before any actual step was taken looking toward its introduction.

Despite the non-utilitarian idea of so many among the early Greek philosophers, the great Alexandrian Museum, founded three centuries before Christ, was made, so far as it was possible in those early days, a technical school, and the principles of science there taught were, for centuries, of direct value in the encouragement of the growth of all the then known industries.

Ptolemy and other astronomers taught seamen the motions of those stars upon which they relied for guidance. Archimedes and other engineers of that time were, at the same time, philosophers and mathematicians, and every art, whether of war or of peace, had its representative practitioners among the attendants at that great seat of learning.

The Roman and Saracen universities and schools, of still later times, were not wholly "gymnastic" and non-utilitarian in character, and the arts often received new developments and were frequently given a new impetus by those discoveries of the philosophers and schoolmen which were promulgated by the investigators themselves, or by their disciples.

The earliest proposal to create a system of education, and a school especially devoted to the development of sciences as applied to the arts, and to the instruction of persons engaged in those various branches of industry which have direct dependence upon science, or in which science is directly applied, was probably made by the Marquis of Worcester, two centuries or more ago, and by contemporary French savans. Nothing was done in Great Britain until long after the system had been inaugurated and had been given form on the continent of Europe.

In this great social and peaceful revolution France took the lead, but only many years after the great philosopher Descartes had urged its inauguration. Descartes proposed the erection of a large lecture hall for each trade, which should be supplied with cabinets of apparatus illustrating the principles of science finding application in that branch of industry, and with collections of all the machines and the tools which were customarily used in the trade. Each of these lecture halls was to be placed in charge of a professor thoroughly familiar with the principles of science, and practically acquainted with the methods of work and the mechanism with which the artisan was to be made familiar; and, under his direction, a systematic course of tuition was to be pursued, having for its object the instruction of the artisan in all those branches of science which were likely to prove useful to him, and in all those details of manufacture and of manipulation which he ordinarily learns, painfully and slowly, only by unguided experience and observation. In art, as in science, systematic instruction only can make the practitioner thoroughly expert and give him a maximum amount of useful knowledge, with the least expenditure of time and of mental and physical energy. It was only in the century succeeding the time of Descartes that an actual beginning was made. For this, the most important step ever taken by any modern nation, France is indebted to the celebrated engineer and mechanician Vaucanson. Throughout his life this great man was constantly collecting curious, useful and ingenious mechanisms, and was unceasingly inventing and constructing devices even more ingenious and intricate than any that he obtained from others. Before 1775, Vaucanson had gathered together at *l'Hotel de Mortagne*, the earliest collection of mechanism and of philosophical apparatus that was ever used to endow a purely technical school. The collections were bequeathed by Vaucanson to the state, and it thus became the germ of the "*Conservatoire Imperial des Arts et Metiers.*"

The people of France are probably the most comfortable and happy nation on the globe—a result which is to be attributed to their frugality and industry, and to the extent to which they have learned to incorporate taste and skill in each branch of an area about equal to that of the State of Texas, of a population nearly equal to that of the whole United States, is the best evidence of the value of such statecraft as has been above described, and of the importance—not to say the vital necessity—of the immediate adoption of a similar system by ourselves.

Germany was the earliest, probably, of all modern nations to recognize the necessity of establishing a complete system of education under the supervision of State officers, and comprehending ihg all portions or the country and all classes of people. Germany was the first European nation in which education became a recognized science, and a science which is second in importance to no one of those to which it has given birth, and of which the growth is so entirely due to its beneficent influence. The first efforts to establish a school system under the direction of the Government, state or municipal, and for the advantage of the whole people, were made a thousand years ago and more, and after the introduction of the art of printing, over four centuries ago, the progress of popular education became rapid and was never interrupted.

Martin Luther was one of the earlier apostles in this most thoroughly "missionary" of all known kinds of labor for the public weal. and the names of Trotzendorf, Sturm, Neander and Comenius are among those which should never be forgotten as pioneers in this noble work; they lived during the sixteenth and seventeenth centuries. They had worthy successors in Spener and Francké immediately after the introduction, subsequent to the Thirty Years' War, of the system of compulsory attendance, the first of whom devised and introduced the modern catechetic method of instruction, while the latter, his pupil, founded in 1696, the celebrated orphan asylum and school at Halle. These great men were succeeded by Basedort and by Pestalozzi.

The complete reorganization, in 1809, of the German school system, and the formal recognition of the fact, now everywhere acknowledged and acted upon, that the government of every State is bound to the community, "as a matter of right, duty and interest," to establish the best and most extended practicable system of education in all branches which are of direct and immediately applicable value to the mass of the people, and to secure the opportunity to the well-disposed and to compel the ill-disposed to take advantage of the privileges thus provided.

As early, at least, as 1757, we find a beginning to have been made in the direction of technical instruction. At that date Councellor Hecker founded the "*Real Schule*" of Berlin, in which, at a time when the Greek and Latin languages and literature were the only subjects taught in the schools generally, it was the declared intention to teach "not words simply, but realities which should be explained from nature, and from models and plans, and which should comprehend subjects which would be useful in after-life."

A change, made by Hecker in 1769, divided the school into three: a classic school, a school of arts, and the German department.

It was only after the commencement of the nineteenth century, however, that trade schools was inaugurated. To-day, the German system of education includes an even more complete system of technical education, and a more general distribution of trade schools, than is even to be found in France.

Said that distinguished British engineer and technicist, John Scott Russell, writing in 1869:*

"Twenty years ago professional duty took me to Germany for the first time. I cannot forget my first impression at the sight of whole nations growing up in the full enjoyment of systematic, organized, I might almost say perfect, education. I had already become acquainted with some theories and forms of edcation. I had read Plato's description of the perfect training for a nation. I was familiar with education in England, in Scotland and in France. I was familiar with elementary school teaching, and enjoyed the privileges of university education and the still higher education of the workshop. I was familiar with the systems of Bell and Lancester, having had personal acquaintance with its authors, and had myself taken an active part in schools of art and mechanics' institutions; but I confess to have been profoundly astonished—I may say humiliated—at the sight of nations whose rulers had chosen to undertake the systematic education of their people, and of peoples who had chosen to bear the burdens and to make the sacrifices necessary to obtain it. I do not know to what men, or class of men in Germany the forethought, organizanization and patrotism are to be attributed which made them lay aside personal ambition, political animosity, religious sectarianism and state parsimony, in order to unite all classes of the people in a unamimous effort to raise every rank in society to a higher condition of personal excellence and usefulness, and, by diffusing equality of education, to extinguish the most grievous of class distinctions."

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* Systematic Technical Education, Lond., 1869.

The German system of technical and of trade education and training is thoroughly complete, and as thoroughly national. Every German State has its preparatory schools, its trade schools, its polytechnic schools, and some have even a technical university.

It is sufficiently evident that in Germany, even more than in France, the governing and the educated classes, instead of standing aloof from each other, and instead of forgetting, as is too generally the case in our own country, those great facts and those imperative duties which every statesman does, and which every citizen should, recognize, have worked together for the common good, and have given Germany a vantage-ground in the universal struggle for existence and wealth which is likely, in the future, to enable that country for many years steadily to gain upon all competitors.

It is now generally admitted that Germany is the best educated nation of the civilized world; there is danger that the United States may, with reason, be reckoned the worst. Germany is gaining a better industrial position daily; our own country is retrograding in all that tends to give manufacturing pre-eminence, except in the ingenuity, skill and enterprise of its people; and on the one great, the vital need of our people is a complete, efficient and directly applicable system of technical instruction and of industrial training, if they are to avoid the successful and impoverishing competition of nations which, like Germany, have already been given that advantage by their statesman and educators a generation earlier. The question whether this comparison shall remain as startling and as discreditable to the people of the United States in future years as it is to-day, is to be determined by the ability of our people to understand and appreciate the importance of this subject, by the interest which the more intelligent classes may take in the matter, and upon the amount of influence which thinking citizens and educated men and the real statesmen among our legislators may have upon the policy and the action of the general and the State governments. The promptness and energy which we may display in an effort to place ourselves in a creditable position among educated nations, will be the truest gauge of the character of the people of the United States. Judged by her progress in this direction, Germany is far in advance of us in the most essential elements of modern civilization.

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Space does not permit the consideration, in detail, of the work in progress in the United States in this direction. The principal colleges and universities are gradually establishing departments in which the sciences are taught in their applications in the various industries, as is illustrated in the engineering departments of Cornell, of Harvard and Yale, and of the University of Michigan and other colleges of both the east and the west, and as is illustrated also by the schools of mines attached to Columbia College, to Purdue and Lehigh Universities, and to other adademic institutions hardly as well known.

Nearly every institution of standing in the country now has one or more of such departments connected with it. In some cases the States have established special schools of agriculture and of the mechanic arts, with the funds derived from the sales of public lands donated to them for the purpose by the general government in 1862, instead of appropriating that fund to the endowment of such schools as departments of established colleges. But whatever has been the method of appropriating the proceeds of the sales of the nine millions of acres there set apart for the promotion of industrial education, the millions of dollars thus granted are doing an immeasureable amount of good in this most important of all directions, in which a government may legitmately take action for the benefit of the people. Experience has shown that, of the several functions of government—the protection of life, of liberty and of property, the encouragement of all legitimate forms of industry, the development of all natural resources and the enlightenment and education of the people—that legislation and that expenditure of public funds which does most toward the education and training of a people, has always proved most helpful of every other means of advancing the interests of the people, and is, directly and indirectly, most effective and renumerative. Evidence is not wanting to prove that this royal gift to the cause of education is already bringing its full return.

In devising a " Plan for the Encouragement of Manufactures," it is evident that we may profit largely by the experience of the foreign nations whose efforts have been described in the preceding pages. It is also undeniable that a few simple principles, and a few important facts may be premised, which will afford a safe basis upon which to proceed in the endeavor to create a thoroughly consistent general system, which shall give the best possible return while demanding the least possible expenditure of time and of labor, either intellectual or physical.

In the effort to improve the condition of our people, aside from those moral and intellectual legislative aids which we are not called upon here to consider, there are two general directions of work, neither of which can be depended upon, alone, to secure the desired maximum possible advantage.

The one is that which tends to improve the capacity of a people as producers, leading to the attainment of ability to add value to crude products by the application of skill in the production of fine materials, or of taste to the ornamentation and beautifying of the products of unskilled labor, and that which leads to the increase of productive capacity in the manufacture of any already known class of product of either skilled or unskilled labor, as by teaching the workmen to work more rapidly, and to facilitate his work by special devices and as by the introduction of machines.

The other is that which either finds a market for marketable products, or which exalts the prices of those products in markets already open to them.

An illustration of a method of the first class is seen in every kind of education and training in the arts ; the second is illustrated by the commercial enterprises daily undertaken by citizens of every nation, and by the operation of the tariff policy of the United States. The latter is directly effective by securing to growing industries the domestic market, and indirectly by artificially protecting them from foreign competition, until they have become sufficiently developed and financially strong enough to sustain themselves abroad, as well as at home, in the face of such competition. It is evident, however, that no system of protection by tariff can open foreign markets to any trade, until those engaged in that trade are capable of placing in the foreign market an equally good or better product than their competitors can meet them with, and at as low, or a lower price.

It therefore follows that no domestic legislation can, by any positive action, open foreign markets. To compete successfully with other nations in the markets of the world, it is necsssary that our marketable products should be placed beside those of our competitors at a lower price than that at which the latter can be profitably sold. To secure this condition, one of two sets of conditions must exist.

(1.) Our working people must either be paid less for their labor—and must, therefore, other things being equal, be less prosperous than competing people—or they must be able to live with equal comfort and to obtain the same luxuries at less cost. These conditions are determined, largely, by the natural conditions of their environment and perhaps quite as much, usually, by the general prosperity of their country and the extent to which the advantages of civilization, and especially of progress in the arts generally, has surrounded them with facilities for living well at small cost.

(2.) Our working people must be so much better educated in the principles and trained in the practice of those arts in which they come in competition with foreign labor that they can introduce their marketable products abroad, competing successfully in quality and price, and yet, that they may, at the same market price, obtain better pay for their labor than their competitor by their ability to make a day's work more productive, either as a result of their higher productive capacity individually or by their use of more, or of better, machinery. These are the conditions which, on the whole, determine the wealth and the position on the social scale of a people, and these conditions are themselves determined by the intellectual and physical capacity of the people themselves, and by their habits—industrious or indolent, frugal, or prodigal— as well as by natural surroundings and their relations, as to location, with other nations.

The consideration of tariff policies and of legislative and executive modes of action, looking to the protective encouragement of industry, need not be here considered at length. It is sufficient to remark in a few words that, as already indicated, plans of governmental action, which are of this character, are of use in cases in which industries demand protection in the home market against foreign competition, either temporarily or permanently, and they cease to be of service when the growing industry has acquired sufficient vigor to sustain itself unaided, or when, prolonged protection failing to give such vigor, it becomes evident that the branch of productive labor thus subsidized, is not well adapted to the conditions under which it is sought to encourage its growth, and that, therefore, the labor engaged therein can be better compensated in other fields of work, leaving the products, thus disadvantageously obtained, to be supplied from abroad.

Such methods of encouragement of industry are ineffective in opening outside markets to any class of domestic products.

It is thus evident that our most important duty is to study those plans, of political and social character, which include the methods already indicated as belonging to the other class; those which—assuming the markets of the world open to free and unrestricted competition, and assuming the untrammelled operation of the great, the universal, and withal the simple, laws of supply and demand—best assist a people in making the most effective use of all the natural advantages which they are afforded by the location, the soil, the climate and the mineral resources of their State, and which most efficiently aid them in acquiring the power of sending into market a maximum quantity of saleable products, and of securing for them a maximum per centage of net profit on each day's labor represented by them.

It is evidently not sufficient to be able to create a large quantity of saleable material, or to obtain simply a high price per pound or per yard. Large sales without profit are hardly as satisfactory as sales of small quantities at good profit. The maximum return is given where the maximum net profit is secured, and where the labor of an hour or a day is made to give highest purchasing power when exchanged, by sale of its product, for such of the necessities, the comforts and the luxuries of life as the worker may be able, or may desire, to secure.

To attain this end, experience has shown that the effort put forth is most effective when it results most largely in the diversification of industries and in the conferring upon the product of labor the greatest value as representative of skill and taste. The diversification of industry enables a territory to support the largest population in any given degree of comfort and of luxury, by bringing the consumer and the producer, the seller and the buyer, into closer relations, and by reducing to a minimum the cost of transportation, that greatest tax upon saleable materials, and especially upon all those more bulky and lower priced materials which, while universally demanded, are least capable of sustaining that tax.

The conferring of value by expenditure of time, skill and taste upon raw or crude materials benefits the producer by making the value of the finished product greater, as compared with that of the crude material purchased, and thus reducing the outlay in money attending the expenditure of given amount of labor and in capital needed to carry on the business; it further brings greater returns for time and labor by giving the opportunity to deal with wealthier purchasers and to offer them a kind of product on which the value of the labor is intrinsically greater. Still further, it lifts the producer of the finer grades of manufactured products above the sharp and desperate competition which is always active, and especially where the unskilled native laborer is continually struggling for existence with the still ruder people who are constantly endeavoring—as are the Chinese in California, to-day,—to supplant him.

The problem to be solved is, then: *First*—To ascertain what are the branches of industry which are best adapted to flourish under the conditions by which we are surrounded and which are, therefore, those which will soonest and most liberally repay us for the efforts that we may exert for their encouragement. *Secondly*—To decide how such industries can be most effectively aided, how the people who are engaged in them can be best assisted to make the most of every condition by which they are naturally favored, and how habits of industry, frugality, with knowledge and wisdom may be best taught them.

In the light of the experience of our own people and of foreign nations, it is not difficult to determine what course is the proper one to pursue, and, assuming that our own people are not less intelligent than are the people of Europe, it cannot be expected that either difficulty or delay will impede the inauguration of such measures as are necessary to the accomplishment of the result desired.

To ascertain what industries are likely to yield the best return for labor expended in them, it is necessary to study the natural and artificial conditions by which they will be affected and, by comparison with the conditions affecting the same industries elsewhere, to determine in what cases, the conditions noted are likely to insure their prosperity in the presence of outside competition. To determine which of the already established branches of industry will best reward efforts made for the promotion of their prosperity, and which, if any, require direct protection, an examination of the condition of such industries is necessary. To secure these desiderata, a system is needed which shall be complete, systematic and permanent, that is to say: this work must devolve upon some department of the permanent executive branch of the government, which department must be presided over by an official who shall understand the methods of collection of industrial statistics and who shall possess the no less important qualifications of thoroughly comprehending the importance of the work and of understanding how the facts ascertained and knowledge thus acquired can be best collated, presented and usefully applied.

The collection and utilization of statistical information is a science which has become tolerably well systematized, and every well administered government includes in its organization a bureau or several bureaus in which statistical information is systematically collected and arranged, and through which such data as are demanded in various departments are supplied in readily applicable shape, together with such general deductions and suggestions as may properly be based upon them.

This subject and this method of attaining the result aimed at is familiar to every student either of political economy or of history, and the collection of statistical information relating to vital and to politico-economical subjects, including invariably the statistics of industry, has been a recognized legitimate and, indeed, essential department of executive government almost from the time of Aschewall of Göttingen, who introduced its science into the German universities a century or more ago. Every important country of Europe has organized Bureaus of Statistics, to which are assigned the duty of collecting and utilizing this class of facts in every department of life, and professorships and schools of statistical science have been many years in operation abroad.

The Parliament of Great Britain is constantly publishing statistical information which is as constantly being made useful in the effort to improve the condition of the British people.

The United States has a Bureau of Statistics at Washington, which has done an immense amount of valuable work by furnishing statistics relating to domestic and foreign industries, and especially facts relating to the methods of work abroad and the ways and the condition of the laboring classes, and showing the causes of successes or of failures in various branches of industry, and thus furnishing a useful guide, from the experience of others. in every department.

A single report* from this Bureau has furnished to the people of the United States a mass of information, which, properly utilized, would be worth more to this country than the cost of supporting the Bureau a decade. One great fact which is well illustrated by the comparisons made in this report, is that of the two methods of securing employment by a people, or by an individual—working at low prices and consequently without ability to secure comforts or luxuries, and working at high prices secured by super excellence of workmanship or superior taste and ingenuity, and consequently leading comfortable, if not comparatively luxurious, lives—the best trained and educated people adopt the latter, leaving no choice to their competitors but to accept the former, and also that, to a large extent, this choice of method is at the option of the people, and that their action is determined by their intelligence. The most successful nations, industrially, are those which not only exhibit most skill and taste, and which have diversified their industries to the greatest extent and have made the value of their productions highest in proportion to cost of material, but they are also those which are attacking the problem of a higher technical and trade education with greatest intelligence and earnestness.

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* Labor in Europe and America, etc., by Edward Young, Ph.D., Chief of Bureau, Washington, 1875.

This one report exhibits with great distinctness the advantages possessed by a nation of ingenious mechanics, competent to compel the steam engine and every kind of "labor-saving machine" to relieve its workers from purely mechanical toil and routine work. It shows the excellent influence for good which has been and may be exerted by trades unions, under an intelligent management which comprehends their real province and their proper functions, and the sad disasters which they may precipitate by ill-considered and illegal action. It thus furnishes a sound basis of fact and experience upon which to base legislative action, and by which to guide individual or associated enterprise, and, on the whole, affords one of the best illustrations of the value of such systematic statistical work.

Some States have also organized Bureaus of Statistics. This was done by the State of Massachusetts in the year 1869, by a law approved June 23d of that year. The State of Pennsylvania took similar action four years later, although the act was rendered to a serious extent inoperative, at first, by neglect to provide the funds needed for its proper maintenance.

The latter Bureau was instructed to "collect, compile and publish such statistics in regard to the wages of labor and the social condition of the laboring classes, as may enable the people of the

State to judge how far legislation can be invoked to correct existing evils," and also to "collect, compile and publish annually the productive statistics of agriculture, mining, manufacturing, commercial and other business interests of the State."

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The first step, after the creation of a Bureau having such functions as that just described, is to secure by its operation all that information which is needed to enable a determination to be made of the relative importance of existing industries, and of the probable value of those as yet undeveloped industries which are likely to flourish within the State. This done, it becomes an easy task to determine how far a general plan of encouragement should be shaped with a view to their separate support.

The next step, the preparation of such a general plan is, when these preliminary steps have been taken, a comparatively easy one.

Every locality which is peculiarly well adapted to the support of any one industry should be given special facilities for the education and training of working people employed in that branch, and for the development of every natural resource and of all advantages of location ; and every proper inducement which legislative action may offer to the capitalist who may be inclined to invest his capital in that branch of industry should be presented to him. * * * * * The Bureau of Industry should make known their respective advantages of position with reference to the sources from which they derive their supplies, and the markets to which the products of their labor may be sent. Wise legislation should be availed of to induce the flow of capital from surrounding districts to these favored localities.

An important step, and one which should be among the first taken, is the fitting of the already established system of public schools to the general system of education as proposed for working people. This modification should begin with the very lowest grade of primary schools. In the selection of text books, preference should be given to those which are found best adapted to combine ordinary routine tuition with instruction in the nomenclature, the use of apparatus, and the methods of the trades with which the child must, in later years, become familiar by their practice in the endeavor to earn a livelihood. In the selection of text books of science, the effort should be similarly made to secure those which contain most information relative to the application of the sciences in the arts of life and which teach most fully and accurately how to apply the principles of science correctly and effectively. An author's neglect to combine the modern technical methods of instruction with the purely "gymnastic" system of mental culture of earlier times should at once condemn his book, and it should be on that ground alone, even if admirable in every other respect, ruled out of every course of instruction. The remark is none the less correct even where the student is not expecting to be compelled to support himself by his own labor or by the direction of the labor of others.

In some parts of our country, the art of drawing is taught to very young children, and it is very properly regarded as one of the most effective means by which the pupil may be made familiar with subjects otherwise difficult of comprehension as well as a means simply of cultivating the powers of the eye and of the hand, and the sense of form and grace. Children of six and seven years of age have produced some of the most interesting exhibits seen at the art exhibitions in Boston each year. Where this interesting and beautiful study can be introduced into the lower schools it may be made a singularly effective aid in the preparation of the scholar to enter upon more advanced courses. By the study of the most elementary system of free hand or of right line drawing from the "round," by drawing from nature rather than from other drawings, as is now customary,—the pupil acquires habits of exact observation as well as of tactual skill, and learns to appreciate minute differences of form and shade. The result is the acquirement of a power of conception of ideas presented, and of grasping and of retaining knowledge with precision, which can probably be given in no other way. The eyes and ears and every sense are rendered both more acute and more fully available for the acquisition of knowledge through all the usual channels of communication between the mind and its surroundings. Teaching drawing as is now usual by reference first to geometrical forms, the pupil is readily led to their combination according to the rules of the art of design, as well as made most thoroughly familiar with the elements of the science of geometry. The teaching of right line and mechanical drawing is as readily made a means of instructing the pupil in the art of designing mechanism, and in the acquirement of a familiar knowledge of standard kinds of machinery used in the trades. Every department of the study thus is capable of being made accessory to instruction in branches now taught only by text books or by lectures.

It is at once seen how it may be possible to introduce this essential department of instruction into schools, even into the most crowded curriculum and into schools of the lowest grade, without reducing their efficiency in any other department of study, and even to the decided advantage of the pupil in every branch of his work in school. This introduction should be at once effected in every school in the State in which it has not already taken place.

The changes here advised—the introduction of the modern system of instruction in artistic and industrial drawing, and the careful selection of text books for adoption in all departments of study with a view to making each useful both in teaching the science itself and to giving the pupil as much familiarity as is possible with the directions and methods of practical application in the arts of life—these improvements in the curriculum, may be at once made in every existing public—or private—school now existing, whatever its grade. No other change is probably now advisable in established schools.

The second step to be taken in the direction of improvement in the status of our people in the matter of education, and in attempting to give them some knowledge of the sciences and the arts which are the basis of all successful industrial operations, is the establishment of trade and technical schools having for their object the instruction of pupils in the principles and the practice of the arts, trades and special methods of the more important departments of industry. As has been stated, some speciai schools of this character have already been established, and are doing a work the value of which cannot be estimated. There is, however, a need of many others, and there is room for more than can be established, undoubtedly, for a generation to come.

Every city of sufficient size to support one, and of which the industries are sufficientlv concentrated, should have a special trade school or schools in which the science and the art of the industry there made a specialty should be thoroughly taught, both by precept and by example. Its theory and its practice, the methods derived from the past, and those which are becoming recognized as the methods of the future, should be taught, and the reasons for every detail, whether based upon the principles of science or upon practical considesations, should be fully explained, and both principles and practice very fully illustrated.

Trade schools fitted up and supplied with a *personnel*, adapted especially to the instruction of pupils in the details of manufacture of textiles, should be established and sustained upon a liberal scale in cities which, like Paterson, are largely engaged in such industries. Schools of the mechanic arts should be founded and liberally endowed in every city which, like Newark, supports a large proportion of its people by those arts. Schools of design should be provided for a city which, like Trenton, would be benefited to an important degree by the introduction of taste and artistic talent and skill in the improvement of its ceramic productions, or which, like every city engaged in textile manufactures, can find useful and paying application for it. Still other schools should be distributed among the more thickly settled and more fertile country districts which are, at the same time best prepared to secure a return for funds so expended and most largely taxed for educational purposes, in which the various departments of agriculture should be studied and taught.

Finally, there should be one or more polytechnic schools or technical colleges—or, still better, a technical university—which should form the apex of this pyramidal system of general education of the workingman's children. In these highest schools, the mechanical and the civil engineer, the superintendents of manufacturing establishments and those who are, or who are to become, proprietors and managers of great industrial establishments and manufacturing enterprises, should here find a place in which to acquire all that the latest experience and the most recent investigation has taught in the department in which they are, or propose to become, engaged. In these highest schools, too, the problems which are continually presenting themselves in practical industrial life, and which can only be solved by scientific and refined, as well as skilled, investigators, should be capable of being attacked by such men assisted by every appliance that modern science avails itself of in such work.

In the choice of the men who are to be entrusted with this vastly important work of the education of the coming generations, the principle that "the place should seek the man" should be persistently and strictly adhered to. The best instructors should be secured for our youth regardless of their nativity or their money-value. The market-value of a man is far oftener below his intrinsic value than is that of any ordinary marketable commodity, and the best schools are those which are made what they are by the best teachers, the world over.

In the selection of teachers for the lower grades of schools the primary qualifications are, as in all other schools, a thorough and exact knowledge of the special branches to be taught, and, what is even more essential, a high capacity for imparting that knowledge to others. The possession of the latter requisite is much more rare than the former, and really good instructors are for that reason difficult to secure and to retain. In the selection of instructors for the highest class of technical schools, another qualification is demanded which is so extremely rare that few universities even can boast the possession of more than a very small proportion of such men. The man who is needed in the school of technology, where advanced students and professional men are to be taught the highest studies applicable in their professional work, must not only be a learned scholar and a good teacher, but he must be an investigator, capable of entering upon original researches and of solving practical problems. He must be able to make scientific investigations which shall "add to the sum of human knowledge," and which shall enable him to supply the many serious omissions and to correct the important errors with which text books abound, wherever they touch the practical side of their subjects. Such men are rare, and students have, from the times of the great men of the Egyptian, the Arabian and the Roman schools to the present time, flocked to listen to them whenever they have heard of the men and become aware of their work.

The scheme of education and training for the working people of a State, as here proposed, and as every thinking citizen mnst see will be demanded ultimately, if not already imperatively needed, comprehends then, the introduction of the recent methods of instruction in drawing into existing schools, beginning with those of the lowest grade and continuing throughout the whole range of instruction until the student leaves the highest of the technical schools; the modification of systems of teaching and the improvement of text books with a view to securing, at the same time, thorough knowledge of the principles of science and a familiarity with its applications in the arts; the institution of special courses of instruction and the foundation of special schools—trade schools—having for their object the teaching of the principles and the practice of the leading industries in localities in which such action would be justified, and finally, the creation of one or more technical colleges in which the highest applications of science to the arts shall have consideration and the highest class of workers shall be taught.

This cannot all be done at once, and it is not probable that it may be found advisable to make haste in this work somewhat slowly, notwithstanding the fact that other nations have already been doing all that is here proposed many years, and that we must continually be subject to the serious difficulties attending competition with rivals who are already so far in advance of us.

It is becoming well understood that the children of the people, as a whole, cannot be given the time needed for the completion of long courses of study. They must leave school early and assist their parents to earn a livelihood for themselves and their family. It has sometimes been attempted to meet this difficulty, in some degree, by providing half-day instruction, keeping the pupil a half-day in school, and sending the child to work in the mill or elsewhere, a half-day. This arrangement has the advantage that it most fully utilizes the available energies of the child. No child should be confined to mental work during any large proportion of the day, and the hours out of school may be made productive by working at a trade, with but little more drain upon the physical powers than would be produced by the same time devoted to play. It may probably be found that this is the only way in which the children of the poorer classes of citizens can be given the needed education. However that may be, it is incumbent upon the State to insure that these children are given the most extended and the most thoroughly useful education that can be by any possibility afforded them.

Aside from this, the inauguration of the changes here indicated presents no serious difficulty. They need involve neither expense nor troublesome changes in the established school system.

The establishment of technical courses of instruction in connection with the existing schools, is likely to be attended with some confusion until they have been fairly inaugurated and have been long enough in operation to accustom pupils, teachers and school superintendents to their detail of working and their management. The more honestly and earnestly the reform and these improvements are taken in hand by those who are charged with the management of the educational system, the more quickly and the more satisfactorily will the work be done. It is but a few years since the high school courses in some parts of the country were divided, giving the advanced student a choice between the course in advanced mathematics and the physical sciences and the course of instruction in the classics. The change which has now become advisable is similar in kind and can be made with no greater difficulty.

The establishment of special schools of instruction in the trades and of schools of technology is a more serious undertaking. The success of the "Whittling School" in Boston, of the schools of decorative art and of design in New York and in other cities, and the operation of the weaving, smith's, machinist's, and other trade schools in connection with the Massachusetts Institute of Technology, the Worcester school and other institutions in various parts of the country, prove the possibility of doing admirable work in this department, even when it is only sustained by the liberality and public spirit of a few private citizens. When the matter is taken in hand by the State, through the regular educational system, of which it properly forms a part, if handled by men of ability and zeal,—by such men as only should be entrusted with this, the most important department of government,—it cannot be expected to succeed less completely. It should, in such hands, prove eminently and immediately successful. The most serious difficulty to be anticipated is that of securing the necessary funds for the erection of buildings suited to such purposes, their outfit—which must include a considerable stock of tools, apparatus and material,—and their operating expenses, including salaries of teachers, who must necessarily be experts in the departments of labor which they are to take charge of, and, at the same time, must be good and experienced instructors. The cost of material, and of wear and tear of tools and machinery in the hands of novices under instruction, must be considerable. The cost of operation for such schools will evidently be no small item for the taxpayer to study. The unintelligent, or the purely selfish citizen will certainly oppose the imposition of such an additional burden upon property holders, and their opposition is not unlikely to prove for a time effective against this great movement, but, as the people become more intelligent, and as the necessity and the advisability and the real economy of such an enlargement of the educational system is more earnestly pressed by the more intelligent, liberal and public spirited of our citizens, a general sentiment will sooner or later be awakened, which will certainly effect the reform. It is already very generally understood that the expenses attending any real advance in educational methods and in the improvement of a school system are invariably liberally repaid by an indirect economy, arising from a more intelligent application of public funds, and the saving of a portion of the loss which is generally chargeable to the dishonesty of officials, or of those—oftener—with whom they are compelled to deal. An increase of the school fund for legitimate purposes is always attended with a more than proportionate return in either a total decrease of taxes or in an increase of general prosperity.

In the operation of these trade and technical schools something can usually be carried to the other side of the account. The products of the labor of a certain proportion of the pupils can be sold to good advantage. The European schools of weaving find a market for a considerable amount of manufactured material, and the designs produced in their schools of design are not infrequently found to have some value. This has also been the experience with such schools as have been founded in the United States. The pupils of the schools of the Cooper Union, in New York, find a good market, frequently, for their work, and the designs produced there and in the schools of decorative art are often taken by purchasers at good prices. By skillful management this system of sale of finished work can be made to not only save some of the expense of maintenance, but it will have a still more important effect in elevating the standard of taste both among manufacturers and purchasers of such products.

Another and a vastly more effective method of accomplishing the inauguration of this system of industrial tuition and training with a minimum of expense, is obviously to bring existing educational institutions into the general system, so far as it can be done. There are already established, by private endowment, a number of institutions in which more or less of this kind of instruction has already been provided for. Nearly every State has a college of agriculture, and many have schools of engineering and of the mechanic arts, either under State or private control. These schools can probably in all cases be made a part of the system, by so arranging the courses of instruction in the lower public schools as to make them preparatory schools for the higher institutions. In the case of the latter being under independent management, the creation of scholarships by the State, to the number that experience may prove to be needed, can probably always be arranged for, and at much less cost than would attend the foundation of State schools of similar grade. So far as these institutions can be thus incorporated into the general system, its complete inauguration will be facilitated and some difficulties avoided.

A system of legislation would be found advisable in connection with this school system by which a certain amount of education of all youth, in some branch of industry, should be made compulsory wherever the pupil had not in prospect some more liberal course of study outside the trade schools. Legislation should also direct the formation of evening schools, in which the elementary studies, including drawing, should be taught to all who choose to attend after the close of working hours. This has already been made a part of the scheme of general education in many places, and it should form a part in every state.

A system of education and training in the industrial arts having been thus provided for the people of all the important trades and for people of every condition, all has been done that can be well done to meet our competitors in the general market, so far as the preparation of our people to do good work can do. This being done, they are placed side by side with the people of other States and of European nations in respect to this element of industrial prosperity. They must then trust to their own intelligence, skill, industry and frugality for success in the effort to acquire the comforts and luxuries of life in the face of the keen competition to which they must expect to be subjected more and more seriously as time advances; for the nations of Europe will each year reap more and more liberally of a harvest coming of seeds sown years before any systematic attempt to form any plan of general industrial education and training was thought of in this country. It remains to be determined by experience how far this tremendous disadvantage will be compensated by the natural advantages which favor our people, and by any intellectual and moral excellencies which may distinguish them.

A plan for the encouragement of domestic industries must include further, some general policy of protection of industries already established, or to be established, by legislation that shall stimulate their growth by aiding the capitalist, however, as well as the working people. No branch of industry can succeed which does not make the employer and the employe alike prosperous. If either retires discouraged from the field, business falls prostrate. To create a body of intelligent, educated and skilled artisans would be useless where no possibility of employment could exist. They could find no employment if capital could find no fair return in investments which should give such labor an opportunity to earn fair wages.

Capital is as sensitive as water, and always flows into those channels in which it can move most smoothly and freely.

In the manufacturing industries, capital always flows most freely where it can find best returns, *i. e.*, where it can buy most cheaply and sell at the best prices. The systematic education and training of artisans enable goods to be made best and cheapest, and thus permit an inducement to be offered to capital which counts upon one side of the sheet. Natural conditions and wise legislation determine how far the other form of inducement—ability to sell to advantage—may be offered.

In regard to this matter, there is but one principle to be adhered to: all legislation must be general, so far as legislation can properly be admitted at all, and all legislation must take the direction of providing against any interference with the natural inflow of capital from abroad, and its employment to the best possible advantage at home. No provision of law which impedes commercial operations can fail to do harm, whether it takes effect upon exchanges of commodities or in transactions between the proprietor and the user of capital. So far as the use of money is affected by legislation, it can only be facilitated by that limited range of legal regulation which secures to the parties to every agreement each his exact right under the contract by which they have bound themselves, enabling each to demand of the other a complete fulfillment of the contract.

Those methods of encouragement of industry which are to be classed with protective measures, and the imposition of a tariff upon importations need not be here considered, since they are entirely beyond the province of state legislation. As has already been remarked, however they are not to be considered as methods of aiding domestic industries to compete successfully in foreign markets with foreign producers, but simply as methods of securing a rapid growth of new industries and protecting them against competition until they have acquired sufficient strength to be able to hold their own unassisted. Such measures are effective, where properly applicable at all, in protecting domestic manufactures against foreign competition in domestic markets, and may be taken with public advantage wherever a branch of industry has naturally a home in the district in which it can be thus "protected."

It need hardly be added that throughout the whole system of legislative and executive action here outlined the welfare of the great mass of the population - and not so much that of any one class, however wealthy or intelligent it may be—is the primary consideration to be kept in mind.

A legislative code is therefore incomplete without thoroughly effective provisions for securing to the citizen of whatever position in life, the liberty to engage himself and to bring up his children in any occupation that he may choose, to make the best bargain for his labor that circumstances will permit or that his necessities may make advisable, and to change his business or enter a new field of labor, whenever or wherever he may decide that it is for his interest to do so, and in any way that he may choose, provided that he at all times deals honestly with his neighbors and commits no offence against the laws of the land. His right to acquire knowledge, and to usefully employ his powers of body and of mind is as indisputable as is his right to "life, liberty and the pursuit of happiness." Recent events have shown that legislation is necessary to secure this right—a right without freedom to exercise which the workers in no department of industry can be thoroughly prosperous.

THE HEAT TREATMENT OF STEEL.

H. C. PETERS.

In this investigation it has been the endeavor to show the effect of heat on steel as far as present knowledge of the subject allows, and to point out methods for practical use more reliable than thumb measures and guesses.

The underlying principle of cooling mixtures has been summed up in the statement, that between certain limits of temperature for the steel, the degree or hardness in a given quality of steel, depends upon the difference in temperature between the steel and cooling mixture, and the rapidity with which the heat is extracted from the steel. With this in mind, it is easy to select such a mixture as will best serve the purpose of the user.

In heating, the vital point is to heat evenly throughout, and to a correct temperature; which temperature denote by W. This entails proper methods of heating, and due regard to fuels used.

To find W, take a flat piece of steel about 4" × 1⅛" × ½" and in it plane a V slot along its longest dimension of sufficient depth to enable it to be easily broken. Heat one end of this hot or until it scintillates. Let the temperature gradually decrease until at the other end, it is at the temperature of the atmosphere. While at these temperatures, quench in the cooling bath which is to be used. Then fracture it. By this means we have a representation of the effect of heat from the temperature of the atmosphere to white heat. Where the steel is nearest the amorphous structure is the temperature W. It now remains to heat steel so that on fracture it will give this structure, and to locate the degree of heat necessary so that it can be easily and alternately reproduced.

To accomplish this the steel is heated in a bath of molten metal (or similar substance) whose temperature is W, and is gauged by a simple and thoroughly practical form of pyrometer. Since the bath is at the temperature W, the steel must rise to that temperature, and cannot go beyond it. Also the surface is not exposed to the air or gases while heating. Hence a correct heating is assured.

The cooling and tempering baths are kept at constant temperatures by the use of thermometers.

In this way uniform heating, cooling, and tempering, are obtained, and hence it is fair to suppose a uniform quality in results.

STEAM CONSUMPTION BY A LOCOMOTIVE WHISTLE.

F. M. GILBERT.

It is a well-known fact that the blowing of a locomotive whistle consumes a large amount of steam, and when the whistle is often used this becomes quite an item.

As Napier's formula applies only to a circular orifice, it is evident that it will not apply in this case where a circular slit is used, so for the exact determination the following method was adopted:

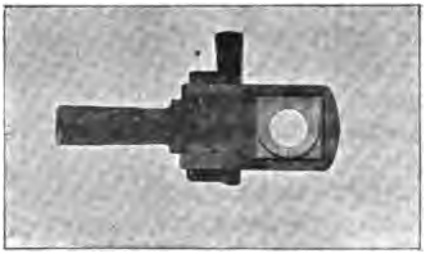
A large size locomotive whistle having an orifice 5¼″ in diameter with an area of ½″ was placed in a steam drum, connection being made from the whistle to the boiler through the bottom of the drum. The drum was connected at the top with a surface condenser, operated by an air pump. In order that the conditions surrounding the whistle might be as nearly normal as possible, the pressure inside the drum, as shown by a manometer, was kept at atmospheric pressure. This was accomplished by running the pump at full head and regulating the vacuum by means of a valve opening into the air from the pipe leading to the condenser, the steam pressure being kept constant by throttling. Running start and stop were made and the condensed water weighed. Three fifteen minute runs were made at 20 lbs., 30 lbs., 40 lbs. and 50 lbs., gauge pressure with the following average results:

20 lbs. gauge = 11.33 lbs. per min.
30 lbs. gauge = 14.17 lbs. " "
40 lbs. gauge = 16.66 lbs. " "
50 lbs gauge = 20.93 lbs. " "

This being the limit at which the air pump would keep the drum at atmospheric pressure, no higher runs were made.

These results are about 30% less than the theoretical ones given by Napier's formula. Computing the consumption by this formula for 140 lbs., the usual boiler pressure of a locomotive and deducting 30% we find the amount used was at rate of 46.55 lbs. per min., or 2,793 lbs., per hour.

THE SIBLEY PIN.



On Wednesday, May 25th, a meeting of the Sibley men was held, at which the question of a Sibley pin was discussed.. From the fact that a pin had already been adopted and a design selected as has already been announced through the columns of the **Crank**, its existence was assured, although only its ardent supporters were ready to say that it was to be a success; however, as a result of this meeting there remains little doubt that the Sibley pin has come to stay and that with a purpose.

The committee which had been appointed made a report, in which the various styles of pin were described, and plans outlined for communicating with all the Alumni of Sibley, in order to apprise them of the action which had been taken and to urge their hearty support. Dr. Thurston was present and spoke in cordial favor of the adoption of the emblem and expressed himself as well pleased with the selection which had been made. He sketched briefly the tremendous growth of Sibley College within the past few years, and the relation of our graduates to each other. The pin seemed a fitting emblem as well as being of a suggestive nature.

In order that there should be no mistake regarding who has the privilege of wearing the pin the following resolutions were read and adopted :

Resolution I. That the pin be known as the Sibley College Graduate Pin, and that it shall consist of the stub end of a connecting rod as now finished.

Resolution II. That the pin .shall be worn only by those who have received the degree of M. E or a more advanced degree from Sibley College.

Resolution III. That the Chairman of this committee be empowered to appoint a committee of three from the succeeding Sibley Senior class, which committee shall constitute a part of the Graduate Pin Committee.

Resolution IV. That said committee shall elect at the beginning of its Senior year three members from the then Junior class, and that this committee of six shall constitute the Sibley Graduate Pin Committee.

Resolution V. That at the beginning of each Senior year the three vacant places upon the Graduate Pin Committee shall be filled as provided in Resolution IV.

Resolutiou VI. That the Graduate Pin Committee be empowered to elect outside the committee and from the Sibley Seniors, a Chairman, who shall call and preside at all meetings of the Sibley students in regard to the Graduate Pin.

Resolution VII. That a permanent copy of these resolutions be handed to the Chairman of the Graduate Pin Committee from year to year.

Resolution VIII. That these resolutions can only be amended by a two thirds vote of all the Sibley students.

A cut of the pin enlarged to twice the actual size, is here given, so that it will be known and recognized ; also it may be well to state that it is made exclusively by R. A. Heggie, of Ithaca, N. Y., and can be obtained from him at any time, by mail or otherwise. It is made of silver and gold, either plain or satin finish, scarf or clasp, for $2.50, or of platinum instead of silver for $5.00.

The Alumni will receive letters very shortly regarding the desirability of securing the emblem, and it is to be hoped that these letters will meet with a cordial reception and hearty response.

SIBLEY COLLEGE EXHIBIT FOR THE COLUMBIAN EXPOSITION, 1893.

The Sibley College exhibit at the Chicago exposition, will consist of photographs and drawings to be shown in connection with the general University exhibit as showing educational methods and apparatus in place, and the distinctive methods employed in teaching.

The principal exhibition, however, will be of the products of the Sibley workshops, and these, thanks to the energy and skill of the foreman of the machine shops, will be creditable alike to the workshops, to the students whose handiwork will be shown, and to the University.

The construction of useful products to any great extent, is a new feature in the Sibley shops, but the experience of the past year has demonstrated that such a system, judiciously managed, can be successfully adopted in shops for the education of engineers The system now in successful operation consists of the construction of a few shop pieces, to acquaint the students with the use of tools followed immediately by a course in actual construction. The products which can be creditably exhibited, have, with few exceptions, been constructed within the past year, or are still in process of construction.

The following list of articles includes those which will be placed on exhibition as showing the handiwork and skill developed in the machine shops:

From the machine shops:

1. A list of shop pieces, designed to secure practice in the use of especial tools, involving hand tools, lathes, planer and milling machines.
2. A Brotherhood engine.
3. A small duplex Gaskill pump.
4. A Worthington duplex pump.
5. Two small upright engines.
6. The Sibley Columbian engine. This engine is of the marine type, vertical, triple expansion, with steam piping arranged so that it can be run as three simple engines, with full steam pressure in either cylinder, or as a compound or triple expansion engine. The diameters of the cylinders are 7, 11, and 17 inches, the stroke in each is 16 inches, and each cylinder is constructed so that it can be used with or without a steam jacket.

A condenser and air-pump will be especially constructed for this engine, and connected directly to the base of the engine. This engine will be one of the largest yet undertaken by any college shops, and its successful completion will be creditable to the Sibley shops, and no doubt will attract much attention at the exposition.

In addition to the above exhibit, it may be considered desirable to send several articles constructed at the shops when in charge of Professor Sweet, among which would be the original straight line engine, and several lathes of Professor Sweet's design.

From the blacksmith shop, foundry and wood shops exhibits will be made showing the character of the instruction, as well as the handiwork of the students.

The mechanical laboratory can show little of its apparatus and its exhibit will be confined principally to photographs and written statements of its educational work.

BOOK REVIEW.

ÉTUDE CALORIMÉTUQUE, de la Machine A Vapeur, por V Dwelshauers-Dery, Engineer Professor in the University of Liege.

To the students who have become interested in the actual determination of the heat losses which occur in the passage of steam through the steam engine, this work will be very useful.

The book is devoted to an exposition of the method of engine testing known as Hirn's analysis, and is of especial value since the author was the first to express this analysis in an algebraic form and adapt it to a form readily applied in testing. The method of the analysis is essentially the same as taught in Sibley College, and needs no comments here regarding its value in determining the actual heat losses which occur in an engine. The book gives the method very fully and also several examples showing in detail the method of testing.

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A PARTING WORD.

Commencement is again at hand, being the sixth time since The Crank commenced its career. The volume which closes with this issue, has been the most successful one in the history of the paper. A look at the index, presented herewith, furnishes reasons for believing that our labors have not been in vain. During the first four years of its publication The Crank maintained the even tenor of its way without much effort. Last year's board infused considerable new life into the journal, but it was reserved for the now outgoing board to raise the standard of The Crank from that of a reasonably well conducted representative of the leading technical college of the country to a place among the professional journals of to-day. We have received many letters of congratulation from college men and others, which have been a source of considerable gratification to us, as they showed that our work was appreciated. Our aim has not been to publish matter that would be of mere momentary interest to our readers, but rather to print valuable papers and results of original investigations conducted at Sibley College which would be worthy of preservation. Some of our readers among the underclassmen may have thought that we were printing more articles of a mathematical nature than was desirable. However, they will yet find that there is no royal road to engineering which leads by a smooth and easy route around the sinuous integral sign and other landmarks of the professional mathematician. In thanking those who have favored us, we can only say that we did our best to merit their kind words, and trust that when the familiar name of THE CRANK gives place next year to the more suggestive one of "The Sibley Journal of Engineering," the same encouraging support will be extended to those who have been selected for its management.

It remains for us to speak a few farewell words to the class of '92. Cornell owes much to its '92 engineers, as they have effectively spread the good name and fame of their Alma Mater. On the other hand, the University has done more for '92 than for any preceding class. Ninety-two is the first graduating class that has had the use of the new library, the new civil engineering building was finished just at the time when '92 needed such accommodations, and the chemical building was completed shortly after the class began the course in chemistry. The Sibley shops have been rebuilt, Barnes Hall completed, the great experimental engine erected, the gymnasium annex finished, and the athletic field opened,—all since '92 registered nearly four years ago,—and all in reality but a few of the more conspicuous benefits that '92 has been fortunate to receive, and assuredly glorious enough to deserve. In return, ever keep the warmest corner in your heart for Cornell University; then may the measure of your success be as great individually as it has been collectively in the class of '92.

A SUGGESTION TO THE ALUMNI OF SIBLEY COLLEGE.

The radical change each successive year in the personnel of the editorial boards of most college publications, breaks that continuity which is the greatest stability of every journal. The details of management of a college news or literary periodical, as such papers ordinarily go, is readily mastered by the successive administrations. As a rule, these publications reach a certain standard of excellence, about which they fluctuate more or less from year to year; their expansion and improvement is restricted to the support of a limited, and largely local, class of readers and advertisers.

That there is a field for a high class technical magazine at Cornell, the experience of the past year leaves not a doubt; that this field lies without and is far greater and more expansive than that of the average college periodical, admits of no contradiction. It is not a question of restriction of circulation and consequent financial inability to improve; assuredly enough practical and valuable investigations to interest and obtain support from the engineering profession at large are conducted every year at Sibley College, to print a monthly issue of twice the size of the present number of the CRANK. But as long as the board of control is radically changing from year to year, there will be that lack of continuity which is absolutely essential for the effective business management required to bring about such a result. A publisher must keep in touch with his readers and advertisers; they have their distinctive traits and peculiarities, which must be ministered to with discretion if the most is to be obtained from them.

The CRANK has, perhaps, during the past year, accomplished nearly as much as can be expected from the present system of "successive" managements. It is our belief, however, that the "Sibley Journal of Engineering" should take a stand in size and in quality of matter, illustratively and typographically, among the few prominent engineering magazines of the day. No undergraduate student, whatever may be his capacity, sagacity, and ability, can afford a sufficient amount of time or command the proper experience at his age and with his opportunities, to accomplish what might be done for the Sibley Journal. Speaking from the standpoint of the experience of the present board of management, with a heartfelt desire for the most good to Sibley College and its Journal, we urge that during the next collegiate year, before the board for 1893--94 is elected from the student body, the management of this paper be made permanent, being placed in the hands of a few well qualified alumni acting jointly with the Professors of Sibley College and a small student representation. Let the Journal be published in a city where the best typographical talent may be obtained, and where the publication may be attended to by resident alumni. Of the entire success of such a venture, we are fully convinced.

THE INCOMING ADMINISTRATION.

The resignation of President Adams, as was expected at the date of issue of our last number, was presented at a special meeting of the Board of Trustees of the University, on the 18th ultimo, and was by them accepted. The retiring president was released from his responsibilities in a most graceful and fitting manner. He was requested to accept a year's salary, and to permit the authorities to arrange with him to sit for a portrait, to be placed in the library among those of the earlier promoters of this great enterprise. Resolutions were inscribed on the minutes, which most admirably summarize the services of the president, and suitably express the appreciation of the Board for his fidelity to his multiferous duties, his wisdom, industry, and sagacity. His influence upon the growth and reputation of the University; his establishment of the existing relations with the State, and his efficiency in extending the influence of the University abroad, are referred to in similarly complimentary words. The resolutions close with the assertion that "his administration will be remembered in the history of Cornell University as equally important to the interests of the institution and creditable to himself; and we tender him, as a scholar, as an educator, and as a man, the assurance of our sincere respect and regard, with our best wishes for his future success and happiness."

The exigency thus brought upon the Trustees of the University has been met and promptly settled, probably much to the surprise of the great majority of the friends of the University, as well as the more distant public.

Professor Jacob Gould Schurman, Dean of the Sage School of Philosophy, was immediately elected to the presidency. He will enter upon his duties at the close of the current collegiate year, July 31st next. Dr. Schurman is of Dutch descent, of Nova Scotian parentage, and an American citizen by naturalization. His great-grand-father, and his grand-father, then a child, lived in the United States, when still a colony, a hundred years ago, and were among those who migrated to Canada at the outbreak of hostilities with Great Britain. He was educated in Canada, and in Edinburgh and London, and, at every stage of his career, has distinguished himself by his genius, his talent, and his fruitful industry. Called to Cornell a half-dozen years ago, he has taken a leading part in all the movements, educational, political and social, which have since occurred. His success as a teacher, as an organizer, and as a philosopher, has rapidly become evident, and promptly led to the establishment, by Mr. Henry W. Sage, of the Sage School of Philosophy, already become the best-known school of its class in the United States.

Dr. Schurman is young, strong, both intellectually and physically, learned in his field, and a power among men. He is liberal of view, fully in sympathy with the ideas, and capable of realizing the ideals, of the Founders of the University; and, if his future does not belie his past, is likely to succeed in doing much toward making it that broad, liberal, "people's University" that they and their successors have aspired to see it become. His administration may not be marked by such an extraordinary expansion and growth of the University as has distinguished that of President Adams, and it is very possible that fewer opportunities may offer to advance into new fields, or to develop the details of organization and administration; but there is never lack of opportunity to build higher and better on existing foundations, and it may be confidently expected that much and good work will be done in the advancement and improvement of the departments already established.

Friends of the technical work of the University, and of Sibley College, even, have asserted that an institution having the peculiar purpose and special foundation which distinguishes Cornell University from the older colleges, should be presided over by a man familiar, as an expert, with its special work, and have even sometimes exhibited the feeling so often expressed when President Adams came into office, that, in the hands of men having no professional relation to that special work, it could not be reasonably expected that those purposes could be fully and satisfactorily promoted; but, whatever may be said of the claims of individuals, we may point to the history of Sibley College during the past seven years as the best answer to that suggestion. President Adams, whose fields of labor, and, presumably, whose sympathies are mainly literary, has certainly, in this direction, carried out his pledge at his inauguration, to be "the President of the whole University." Sibley College and its "liberal practical education" have not suffered at his hands. With larger means, much more might have been done; but the work accomplished is sufficiently impressive, and no failure can be ascribed to unkindly or unfair opposition in the Board of Trustees, in the President's office, or in the Faculty. All have worked together to carry out, honestly and earnestly, the great work confided to them. The results have exceeded all expectations, and in all departments as well as in those under the especial protection of the authorities. Every friend of Sibley College and its work will thank the retiring President and his coadjutors, without exception, for this honest and helpful aid.

The attitude of the incoming President is easily determined by reference to that admirable address, "The People's University," delivered before the University on Founder's Day, 1888, in which he asserts that "the unparalleled prosperity of our University has been owing to the character of its constitutive idea; to that principle of universality and equality which it is the undying fame of Ezra Cornell to have conceived, and here first applied to education." He goes on to say: "The analysis of soils is as important as the analysis of literature; the steam-engine is as sacred as Greek; philosophy is not more venerable than road-making; a house is as rational as the geometry which it embodies. We must no longer dream that the section of knowledge we cultivate is the holy of holies. Every atom of the universe is equally worthy of regard.

All are but parts of one stupendous whole,
Whose body Nature is, and God the soul."

The new President will do his best for Cornell University as a whole, and none will rejoice more than he in the prosperity of every department. The progress of Sibley College will continue to be limited only by the talent and endeavor of its own Faculty and students, and the extent to which its many friends can give it material support. Much of help and nothing of harm will come of the inauguration and during the administration of Dr. Schurman.

CRANK SHAFTS

—Please pay your subscription. This issue completes Volume VI.

—The Edison General Electric Co. has presented Sibley College with one of their new automatic arc light dynamos together with a full complement of arc lamps.

—The editorial board of the CRANK for next year will be made up as follows: C. J. Barr, Editor-in-Chief; J. M. Thomas, Jr., Business Manager; A. H. Alberger, I. C. G. Wilkins, L. S.

Louer, M. B. Edgerton, C. L. Inslee. Professors R. C. Carpenter, H. J. Ryan and J. H. Barr will constitute the associate board.

—The annual Commencement address at the Ohio State University will be given this year by Dr. Thurston, who has on previous occasions been compelled to decline. The Commencement at Columbus is this year a week later than at Ithaca. The Ohio institution is, like Cornell, a land grant college, founded under the provisions of the Morrill bill of 1862, and, as in most of the western states, is the recognized state university.

—Captain Ericsson many years ago designed for the Delaware Iron Works, of New York, a small steam engine intended to drive the electric lighting "plant" of that great establishment, which is now in the possession of P. F. Collier, the proprietor of "Once a Week." The engine was especially remarkable as being designed and regularly operated at the speed of 1,200 revolutions a minute, at a time when one-fourth that speed was usually thought enormous, and, in fact, is still considered great. At the suggestion of the director of Sibley College, who knew Captain Ericsson, and was familliar with the circumstances, Mr. Collier has presented this machinery to the University for use in Sibley College. It is acceptable both as having historical interest and for purposes of experiment and instruction in the laboratory.

—The skeleton model of the steamer "Rockaway," recently presented to the University for the graduate school of marine engineering is now in the lecture room of that department. The steamer was formerly one of those plying about New York harbor and to Rockaway beach, but foundered off Atlantic city some years ago. A law suit followed, in the course of which this model, representing the whole framing of the vessel in its minutest detail, was made from the original shipbuilder's drawings, under the eye of Mr. Gustave Hillman, a distinguished naval architect, who has already done much for Sibley College. The model is about ten feet long and is considered by experts to be worth between $750 and $1,000. It is presented by M. H. A. Bourne, vice president of the Old Dominion Steamship Co., of New York, with the remark: "Its mission with this company is ended, and we thought it might be of value to your college as an object lesson to your students, and we beg leave to present it to the college, with the compliments of this company."

PERSONALS.

Professor S B. Newbury is expert chemist for the Warner Cement Co., of Syracuse.

Assistant-Professor McDermott, Instructor Royse, and Instructor Reid and family will spend the summer in Europe.

'87.

G. W. Stephens has charge of winding the dynamos at the Thomson–Houston Co., Lynn, Mass.

E. C. Boynton is now with the Thomson–Houston Co , Lynn, Mass., where he has charge of the building of heavy street railroad generators.

C. A. McAllister, '87, has passed No. 1, among 14 candidates for admission to the Revenue Marine Service as an Assistant Engineer. His name will soon be sent to the Senate by the President, for confirmation.

'89.

W. W. Churchill is with Westinghouse, Church, Kerr & Co., Pittsburgh, Penn.

'90.

E. S. Bowen is with the McIntosh, Seymour & Co., Auburn, N. Y.

'92.

Charles Camp will spend the summer in Europe.

R. L. Gifford is with A. Gottlieb & Co., Chicago, Ill.

R. T. Burwell is at Audobon Park, New Orleans, La.

W. A. Paris is with the Schuyler Co., at Middletown. Conn.

H. B. Clark is with the Hydraulic Machine Co., Pittsburgh, Pa.

G. W. Bacon and H. W. Hull have accepted positions in Scranton, Pa.

E. Y. Ware has accepted a position with the Thompson–Houston Co., Lynn, Mass.

F. B. Corey has accepted a position with the Elektron Manufacturing Co., at Springfield, Mass.

F. J. Tone will leave Pittsburgh and accept a position with the Thomson–Houston Co., Lynn, Mass.

C. H. Werner has accepted the position of associate editor of *Cassier's Magazine*, the illustrated engineering monthly.

R. T. Mickle will be with the Pusey & Jones Co., Wilmington, Del., next year, engaged in the construction of marine and paper machinery.

C. L. Hoyt has accepted a position as instructor in mechanical engineering, in the Michigan Mining School, at Houghton, Mich., for the ensuing year.

'93.

A. T. Baldwin is with Sweets Manufacturing Co., Syracuse, N. Y.

H. C. Peters will complete his course this year, and has secured a responsible position with the Morse Twist Drill & Machine Co., of New Bedford, Mass.

E. P. Chapin is with the Somersworth Machine Co., at Dover, N. H., working in the pattern shop. Mr. Chapin will probably return next fall to complete his course and graduate with his class.

CURRENT EVENTS.

'93's *Cornellian* appeared on Tuesday, May 31st.

The '86 Memorial Prize was won by E. I. White, '93.

'92 banqueted on Friday, May 20th, at Journal Hall.

May 28, at Percy Field, Lacrosse, Toronto 10, Cornell 4.

The games at Berkley Oval resulted in Harvard winning 48 points, Yale 38, Princeton 14, Columbia 10, Cornell 0.

Professor J. G. Schurman has been unanimously elected President of the University, by the Board of Trustees.

The '94 *Cornellian* Board has been organized with C. L. Brown, Editor-in-Chief, F. B. Downing, Business Manager.

Next year's *Era* Board consists of Northup, '93, Jaquish, '93, Jameson, '93, Tompkins, Landfield, Mayo, and Fordham, '94.

Dean White has resigned his position as Dean, the same to to take effect at the end of this college year. He retains his Professorship, however.

The electric railway to the campus seems to be an assured fact, as rails have been distributed and work commenced. It is estimated that 400 H. P. will be needed at present.

The *Sun* Board for next year is as follows: Howland, Editor-in-Chief, Darling, Business Manager, Hopkins and White, '93; Slater and Ahern, '94; Young, '95; Hanson, L. S.

Two Regattas will be held on Cayuga Lake. Columbia Freshmen and Cornell Freshmen row on June 8th, Wednesday, and one week later, the 15th, the 'Varsity race between U. of P. and Cornell occurs.

The editors of the *Cornell Magazine* for next year are: Instructor William Strunk, Editor-in-Chief, H. C. Howe, C. E. Ladd, Margaret Otis, G. A. Schriver, E. I. White, and H. G. White, Business Manager.

In the Passaic Regatta. on Monday, May 30, Cornell won the Senior eight-oared race beating the New York Athletic Club crew by one boat length, time seven minutes twenty-one seconds, thus breaking the record by twelve seconds, for this course.

May 20, baseball, at Percy Field, Cornell 9, Lehigh 1. At Oberlin, Cornell 5, Oberlin 3; at Cleveland, Cornell 10, Cleveland Athletic Club 8; at Detroit, Cornell 7. Detroit Athletic Club 5. The Cornell-Michigan game was not played owing to delay in arrival of U. of M. team in Detroit. U. of P. will probably play Cornell at Ithaca June 11.

COMMENCEMENT WEEK PROGRAM.

SATURDAY, JUNE 11TH.

8.00 P. M.—Prize debate, by Seniors of the School of Law, in Barnes Hall.

SUNDAY, JUNE 12TH.

3.30 P. M.—The Baccalaureate sermon, by the Rev. John A. Broadus, D.D., LL.D., in Gymnasium Hall.

MONDAY. JUNE 13TH.

1.30 P. M.—Woodford Prize Speaking, in Gymnasium Hall.

8 00 P. M.—Concert by University Glee Club, at Wilgus Opera House, for benefit of crews.

TUESDAY, JUNE 14TH.

9.30 A. M.—Class Day Exercises at Gymnasium Hall.

11.30 A. M.—Class Day Exercises on the Campus.

9.90 P. M.—Senior Reception at Gymnasium Hall.

WEDNESDAY, JUNE 15TH.

9.00 A. M.—Annual Meeting of the Board of Trustees in Morrill Hall.

10.00 A. M.—Annual Business Meeting of the Alumni in Library Hall.

2.00 P. M.—Reunion of the class of '87 in Barnes Hall, of the class of '82 in Library Hall, of the class of '77 at Ithaca Hotel, and of the class of '71 at Ithaca Hotel.

4.00 P. M.—University Boat Race, Pennsylvania *vs* Cornell.

THURSDAY, JUNE 16TH.

9.30 A. M.—The Twenty-fourth Annual Commencement, in Gymnasium Hall.

1.00 P. M.—University Banquet.

APR 26 1948